THE

JOURNAL OF GEOLOGY

JANUARY-FEBRUARY, 1912

MAY 3 1913

THE PERMO-CARBONIFEROUS OF NORTHERN NEW MEXICO

S. W. WILLISTON
The University of Chicago

E. C. CASE
The University of Michigan

The age of the Red Beds of the Rocky Mountain region has long been in doubt. They outcrop extensively along the eastern foothills, extending across Wyoming from the Laramie Mountains to the Wind River Range, thence through eastern Utah and western Colorado, with extensive exposures in the southwestern part of that state; in various places in northern New Mexico, from the San Juan region east; southwestward in the Ft. Wingate region; and along the eastern part of the same state. On the plains are extensive outcroppings in southwestern Kansas, thence across Oklahoma into the northern and western parts of Texas. Vertebrate fossils of Triassic age have been reported from the Lander region (Williston, Branson), Como and Red Mt. (Reed and Williston) in Wyoming; from northeastern Utah (Lucas); western Colorado (Cross); northern New Mexico (Cope); Fort Wingate, New Mexico (Yale collections, Shufeldt); Pan Handle (Cope), and Claremont, Texas (Brown). The fossils, consisting chiefly of phytosaurs and labyrinthodonts, agree, for the most part, so closely with those of the Keuper of Europe that their horizon may be confidently fixed as Upper Trias. Below the horizon yielding

MAY 3 1913

these remains there are rocks of about nine hundred feet in thickness in the Lander region, and perhaps more in the southern region, which have been hitherto supposed to be utterly barren of all fossils, whether vertebrate or invertebrate; and there are at least three hundred and fifty feet immediately underlying strata of certain Upper Trias age which have never, in any place, yielded fossils.

Everywhere characteristic of the uppermost beds, from Lander to New Mexico, Kansas, and Texas, are from five hundred to possibly a thousand feet, as estimated, of barren or almost barren measures, characterized by the lighter colors of the sandstones, often of aeolian origin, and more or less interspersed or capped with massive beds of gypsum, as at Lander, in Kansas, Texas, and New Mexico. The age of these upper beds throughout is assumed to be Triassic, but we know of no evidence whatever, save the color of the rocks, to differentiate the uppermost of them from the Jurassic,[1] which lie in some places quite conformably above them. At Cañon City, Colo., the Hallopus beds, lying conformably immediately above the Red Beds, have been supposed by Marsh to be either of Lower Jurassic or Upper Triassic age, and the senior author from an examination of them agrees quite with his opinion. With this possible exception there are no fresh-water deposits in North America of Lower Jurassic age, the beds lying immediately above the Red Beds, whether conformably or not, being either the marine Jurassic (Sundance), or Morrison of uppermost Jurassic or lowermost Cretaceous age.

At the base of these barren measures of Upper Trias or Jura-Trias age, in the Lander region, are thirty or more feet of massive sandstones, red, whitish, or variegated in color, underlain by pebbly conglomerates and clays, in which occur the remains of vertebrate fossils, if not in the sandstones themselves. Below these fossiliferous beds, in this region, are nine hundred feet of red sandstones and clays, as recently accurately determined by Branson (*in lit.*) lying conformably, both with the overlying Upper Trias sandstones and the underlying beds of Pennsylvanian age (Embar beds, Branson), in which no fossils of any kind have ever been detected, though

[1] These measures were referred by Cope to the Jurassic many years ago (G. M. Wheeler, *Annual Report*, 1875, pp. 78 ff.).

we are of the opinion that careful, persistent search in the lower two or three hundred feet will be rewarded with vertebrate remains. In Kansas the Red Beds have been estimated to be one thousand feet in thickness and said to be utterly unfossiliferous, by Cragin

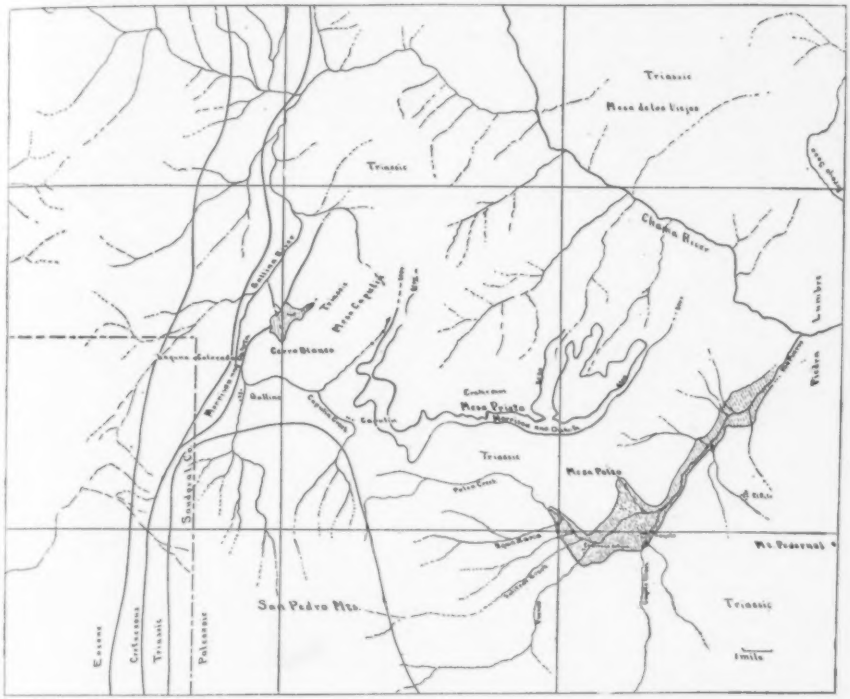


FIG. 1.—Map of Mesa Prieta and adjoining country. The fossiliferous Permo-Carboniferous is shown in the areas indicated by broken lines. Comparison with the Jemez topographic sheet will make details evident.

and Hay. From just south of the Kansas line Professor Gould some years ago obtained very typical remains of the amphibian *Eryops* (*E. Willistoni* Moodie), a characteristic "Permian" fossil, and it is very probable that intelligent search will show, somewhere between this horizon and the barren beds of southern Kansas, the

characteristic massive sandstones and phytosaur remains, more probably so since such fossils have been actually found not far to the west.

Cross has reported unconformity of the Red Beds in western Colorado, but it has been our experience, wherever we have examined them, that they lie conformably throughout, so far as stratigraphical evidence indicates. In Kansas, Oklahoma, Texas, and eastern New Mexico they seem to be thicker, perhaps reaching two thousand feet in their totality. In northern New Mexico our observations the present year give a thickness of not over sixteen hundred feet, while in the Lander region their total thickness is fourteen hundred and forty feet, as recently accurately determined by Professor Branson.

More than thirty years ago, the late David A. Baldwin collected from the Red Beds of northern New Mexico, which he considered of Triassic age throughout, considerable quantities of vertebrate fossils, the most of which are now preserved in the museum of Yale University, and the remainder in the American Museum of New York City. At the time of their collection two or three very brief descriptive papers, referring them to the Permian, were published by the late Professors Marsh and Cope, but without giving any further information as to the locality of their origin than simply New Mexico. Within the past few years the present writers have published further notes and descriptions of the remains in these collections, with more definite information of their occurrence. With more precise information kindly given by Professor Schuchert an expedition was planned to explore the region the past summer. This expedition, composed of Mr. Paul Miller of the University of Chicago and the present writers, entered the field the early part of July from Espanola, near the mouth of the Chama River, with Abiquiu as the chief base of supplies. Dr. v. Huene was a member of the party for three weeks. Abiquiu, one of the oldest settlements in the United States, is located twenty-seven miles northwest of Espanola on the Chama. It is our pleasure to acknowledge with gratitude the kind favors shown us here by Mr. Henry Grant.

From Abiquiu our entrance into the Red Beds was made in the

famous cañon known as El Cobre, so named because of the indications (indications only) of copper long known there. From thence the expedition followed the valley of the Puerco to the embouchure of its chief tributary, the Poleo (Arroya de Agua). Later a brief trip was made to the valley of the Gallina, and as far west as the Wasatch deposits in Sandoval County.

From Espanola to Abiquiu the road follows the sandy valley of the Chama, bordered by Tertiary deposits, coarse white sandstones, often eroded into typical badland forms, and leading up to lava-capped table-lands. Three or four miles west of Abiquiu the Tertiary sandstones lie immediately upon heavy beds of red clays and red sandstones of Triassic age. In the immediate stream bed

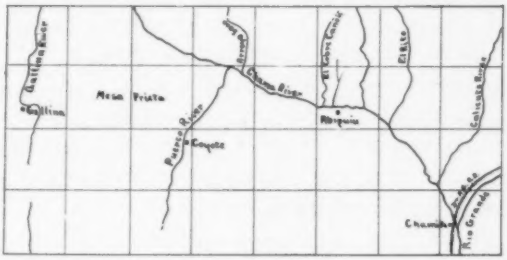


FIG. 2.—Map of region about Abiquiu showing location of El Cobre Cañon

of the Cobre creek we observed conglomerates twenty or more feet in thickness, composed of quartzite bowlders reaching six or eight inches in diameter, and almost devoid of binding matrix. Farther northwest and toward the entrance into the Cobre basin there are fifty or more feet of red and variegated clays, which in turn are underlain by from fifty to seventy-five feet of more massive sandstones, with a more or less persistent conglomerate pebbly layer beneath them, yielding phytosaur remains. It is through these sandstones that the outlet of the basin occurs in a narrow but not deep gorge.

El Cobre Cañon or basin is formed by the erosion of an unsymmetrical dome-shaped anticline more or less faulted on the northeastern and southeastern sides, the brim formed everywhere by the massive sandstones of basal Upper Triassic age, the strata sloping

in all directions, but chiefly east and west. The basin thus formed is about two and a half miles in its greatest extent, in a north-and-south direction. Its very steep walls, for the most part about seven hundred feet in altitude, attain their greatest height in the northwest part, where the altitude may exceed eight hundred feet, and where the Permian exposures are the greatest.

The erosion of the floor of this basin, acting on the beds of alternating sandstones and clays, has formed a series of steps or low cliffs, which for the most part dip at a small angle toward the west. Toward the sides and upper end of the cañon these ridges become more prominent, frequently forming high bluffs and cliffs. The lowermost beds in the cañon are deep chocolate-colored sandstones and fine conglomerates; the latter weather into low, rounded hills, frequently streaked with greenish layers. Bone fragments were found in these layers in various places in the basin. Above these darker colored sandstones are more massive sandstones, weathering more or less whitish, which ascend at the north end of the cañon to perhaps three hundred and fifty feet above the stream bed. All vertebrate fossils that we found, of Permian age, were below these sandstones, which form a fairly definite horizon about the basin, and which may be taken as the lower limits of the Trias.

It has been questioned by us elsewhere whether the vertebrate fossils found in Texas, Oklahoma, southern Kansas, Illinois, and Pennsylvania are really of Permian age. At the south side of the cañon, the junior author found a perfect cast of a *Spirifer*, identified by Professor Schuchert as *S. rockymontanus* Marcou, a form occurring in Colorado in the Pennsylvanian. Though the specimen was found free, so that its exact horizon could not be determined, its excellent preservation proves conclusively that it had not been carried far from its original bed, and inasmuch as vertebrate fossils are found in the deepest strata of the cañon it seems quite certain that the specimen came from an intercalated bed among those yielding so-called Permian vertebrates. No other explanation seems possible. It is the conviction of both the present authors that the lowermost at least of the strata yielding vertebrate fossils are of Pennsylvanian age, and this conviction is strengthened by the known position of the vertebrate horizons in Texas, Kansas,

Illinois, and Pennsylvania, that of the last-named region definitely known to be Pennsylvanian.

Below is given a section (Section I) of the west wall of the Cobre Cañon as far down as the horizons yielding fossils of paleozoic age. It must be especially remembered, however, that this, as

SECTION I

EL COBRE

Yellow sandstone and conglomerates	75	Upper Trias	
Purplish and gray clays	40	"	
Purplish sandstones	20	Lower Trias?	Barren
Purplish clays and nodular sandstone	25	"	"
Red sandstone	5	"	"
Bright red clay	35	"	"
Purple clay	12	"	"
Bright red sandstones	22	"	"
Coarse purplish sandstones	12	"	"
Bright red clay with greenish nodules and purplish bands	100	"	"
Coarse, hard purplish sandstone	8	"	"
Bright red clay and sandstone	65	"	"
Hard red and purplish sandstone	6	"	"
Bright red sandy clay, with purplish streaks	90	"	"
Purplish and dark brown clay	22	"	"
Red clay and hard red sandstone	30	"	"
Hard purplish sandstones	35	"	"
Red clay	7	?	
Purple sandstones	3	?	
Red clay	22	?	
Permo-Carboniferous: red, brown sandstones and clays, fossiliferous			

also the other section given in this paper, will not apply in detail to any other place, since it has been our experience in the Red Beds that detailed sections made in any given place cannot be depended upon perhaps a quarter of a mile away. The top of this section, as already stated, yields vertebrate fossils of Upper Triassic age, and some of the Triassic vertebrates described by Cope from New Mexico came from the El Cobre Cañon.

A survey of the surrounding country from the summit here, as also from the Piedra Lumbre, shows everywhere these basal Upper Trias rocks as the lower or lowermost exposures.

From the El Cobre Cañon the expedition turned westward on the Chama to the mouth of Cañones creek, and then southwest across the Piedra Lumbre Mesa to El Rito, or "branch" of the Puerco. The top of this mesa is of Upper Triassic age, and, near the base of Mt. Pedernal, which rises several hundred feet above the mesa, appears for the first time the heavy layer of gypsum marking the upper limits of the Red Beds, or so-called Trias. From the top of this mesa a good view of the adjacent country is afforded. To the north is the Mesa de los Viejos, with the Chama apparently occupying a fault line between, and the Arroya Seco in a valley formed by the basal Upper Trias rocks sloping from the brim of the Cobre Cañon on the east and the superincumbent Triassic rocks on the west. To the west lie the Mesa Prieta and the smaller Capulin Mesa, separated by the Puerco, Chama, and Capulin streams, whose courses seem to have been influenced strongly by the faulting and dipping of the Trias.

The Puerco to the mouth of the Poleo has cut down into Permian strata, which attain their greatest exposure on the Poleo about one mile from its mouth. Our first camp was made on the Poleo (Arroya de Agua), about one mile above its confluence with the Puerco.[1] Near the junction of the two creeks there is a steep walled cliff of Permian rocks about a hundred feet in height, with a more or less flat table-land above it a mile or so in extent separating it from the Trias above. Farther west, where the Permian rocks find their greatest exposure, and where the Baldwin quarry is, from which so many of the fossils in the Yale collection came, the very steep bluffs, in many places so steep as to be unclimbable, are about seven hundred feet in height, composed of alternating red sandstones and clays, with white and purple sandstones, clays, and conglomerates at the upper part, corresponding quite to the massive sandstones forming the brim of the Cobre Cañon, and which form the top of the Mesa Poleo, dipping northward to the foot of the Mesa Prieta. Phytosaur bones were found at the base of this white sandstone and in the pebbly conglomerates immediately underlying them. Permian fossils were found only in the lower-

[1] This Puerco creek is not the one which gave origin to the name of the Puerco formation, a stream by the same name farther to the southwest.

most three hundred feet of these exposures, the intervening three hundred feet of more or less vertical red clays and sandstones here, as everywhere else in the Rocky Mountain region, being quite barren. These rocks lie here, as elsewhere, apparently quite conformable with the superincumbent and subjacent beds, and doubtless represent the Lower Trias and perhaps more or less of the Upper Permian. The section of the bluff herewith given was made opposite our first camp on the Poleo, about one mile from the mouth of the creek; as is the case with the section at El Cobre, it can be depended upon only for a short distance on either side; the strata often change abruptly from sandstones to clays and vice versa.

On the north side of the immediate valley of the Poleo the strata dip northward to the walls of the Mesa Prieta; immediately south of the creek they dip abruptly southward. About two miles above the mouth of the creek the beds bend down sharply and disappear beneath the alluvial deposits of the creek bed, doubtless indicating the line of a fault. Beyond this point the walls of the Mesa Prieta, formed exclusively of Upper Triassic and superincumbent beds, descend to the immediate valley of the Poleo and Capulin creeks.

The Mesa Prieta rises about fifteen hundred feet above the beds of the Poleo and Capulin. Near the middle of the bluffs, at about the 8,000-foot line, there is a heavy bed of gypsum, which is taken to be the upper limits of the Trias, though, as we have said, in the entire absence of all fossil remains through four hundred feet of these beds at least, everywhere, their age is assumed simply from their color—evidence, to say the least, that is exceedingly dubious, the more so from the fact that there is no petrological distinction between the Trias and Permian. Above this gypsum layer are the brownish and purplish shales of the Jurassic[1] and the lighter colored sandstones of the Cretaceous all lying quite conformably with the Red Beds below.

About a mile and a half beyond the little settlement called

[1] The beds immediately overlying the gypsum have been called Dakota by Darton (*Bull. U.S.G.S. No. 435*) and Shaler (*Bull. U.S.G.S. No. 315*, p. 262), but without any evidence therefor. We searched in these shales for fossils, but without success. Elsewhere the beds overlying the Trias are either the marine Sundance (Wyoming), the Hallopus beds (Cañon City, Colo.), Morrison (Southern Wyoming), or Lower Cretaceous (Kansas).

SECTION II

POLEO CREEK

Gray sandstones, mostly even grained with pebbly conglomerates and shales below. Phytosaurs	30	Upper Trias	
Softer gray sandstones, weathering into sand	30	?	
Sandy clay, with beds of thin black shale; plant remains, fossil wood	40	Upper Trias?	
Sandy clay, black and green	12	Lower Trias?	Barren
Purplish sandy clay	6	"	"
Coarse yellow sandstone	33	"	"
Loose gray sand	6	"	"
Green and purplish sandstones	3	"	"
Gray and purplish sandstones	12	"	"
Hard clay, variegated and jointed (cliffs)	3	"	"
Purplish sandstones and red clay	30	"	"
Loose white sand with beds of red clay	40	"	"
First red nodular layer	6	"	"
Soft fine-grained, light red sandstones, cross-bedded, forming tops of pyramids and cliffs	6	"	"
Soft fine-grained, light red sandstones, cross-bedded with lighter bands of pebbles	3	"	"
Second red nodular layer, with clay	3	"	"
Red clay	2	"	"
Coarse cross-bedded sandstones	6	"	"
Third red nodular layer	6	"	"
Red cross-bedded sandstones	12	"	"
Dark red and green clay	3	"	"
Coarse red and green sandstones	17	"	"
Hard red sandstones, cliffs	3	"	"
Red sandstone and clay with thin band of harder sandstone	18	"	"
Hard, red coarse sandstone	3	"	"
Red clay	35	"	"
Red sandstone, bluffs	23	Base (?) of Trias	
Red sandstone with thin seams of clay, reptile bones	18	Top (?) of Permian	
Red clay with thin nodular layers	55		
Dark red, coarse sandstones (cliffs)	6	Permian, fossiliferous	
Red sandy clay	35	"	
Dark red, coarse sandstone, jointed	18	"	
Red clay, even texture, vertical rain erosion	50	"	
Dark red clay	8	"	
Red shaly clay	17	"	
Heavy gray sandstones	25	"	
Red sandstones and clays	?	"	

Capulin a stream flows into Capulin creek from the north along the line of a fault which divides the Mesa Prieta from the Capulin Mesa. The strata of the Mesa Prieta at this point dip slightly northwest, but those of the Capulin Mesa dip east and northeast. The west face of the Capulin Mesa rises a thousand feet or thereabout above the valley of the Gallina River. Just north of the Cerro Blanco there is a high red wall similar to that north of the Poleo creek, the uppermost rocks bearing phytosaur remains. It is confidently believed that the lowermost exposures here are of Permian age, but no fossils were found.

There is a sharp break between the Capulin Mesa and the Cerro Blanco. The rocks of the latter dip sharply to the west, and are overlain by the Jurassic shales and the Cretaceous sandstones and shales. At the foot of these Upper Triassic rocks, north of Cerro Blanco, and opposite the face of the Capulin Mesa bluff before referred to were found various small fresh-water invertebrates, and bone fragments referred provisionally to the genus *Coelophysis* Cope. The horizon of these remains can hardly be less than one hundred feet above the basal Upper Trias sandstones, and, in all probability, the original types came from the immediate locality whence the fragments were found by the junior author. The Cerro Blanco takes its name from the massive beds of white gypsum which cap it, descending steeply below the creek bed to the south and dipping to the west. From the top of the Cerro Blanco one can look miles to the north and west, and the view therefrom is a revelation to the geologist. To the east lie the mesas of more or less horizontal rocks of predominantly Upper Triassic age; to the west the strata are deeply tilted and eroded into valleys; a few miles farther west the beds of the Wasatch badlands lie horizontally upon the uptilted edges of the Mesozoic strata.

Upon the whole, the general features of the Red Beds in northern New Mexico, as in many places elsewhere, may be summarized as follows:

The Upper Trias rocks, about six hundred feet in thickness, perhaps more, are predominantly softer and lighter colored, often orange colored, yellowish and whitish, and more aeolian in character, with the upper or uppermost beds more or less gypsiferous.

These beds, as in the Lander region, have basal sandstones, reddish or white, with conglomerate and clay layers below them yielding phytosaur and labyrinthodont bones (both types were found at El Rito), corresponding well with like vertebrates from the Keuper of Europe. Below these beds there are not less than three hundred and fifty feet, in the Lander and Kansas regions perhaps nine hundred feet, of more uniform red sandstones and clay layers, usually weathering into more vertical bluffs, that are utterly barren of all fossils and supposed to be of Lower Triassic and Upper Permian age. Below these and conformable with them, in New Mexico and probably elsewhere, are not less than three hundred feet, probably more, of prevailing coarser and darker colored, often brownish sandstones, and dark-colored clay beds, yielding vertebrate remains hitherto considered to be of Permian age, but which in all probability are in part at least of upper Pennsylvanian age.

ON THE DISTRIBUTION OF LOWER TRIASSIC FAUNAS[1]

JAMES PERRIN SMITH
Leland Stanford Jr. University, California

No formation has added more in recent years to our knowledge of ancient faunal geography than the Lower Triassic. In this epoch we now know three distinct and widely distributed interregional faunal zones, which are truly bench-marks in correlation. These are in sequence upward: (1) the *Meekoceras* zone; (2) the *Tirolites* zone; (3) the *Columbites* zone. They do not have the same distribution, nor are the relationships of the various regions constant for the successive epochs, showing that there was considerable change in physical geography during the Lower Triassic. Critical studies of these faunas from Siberia, India, Madagascar, the Indian Archipelago, and western America have made it possible for us to understand the ancient faunal geography in a way that was impossible a few years ago.

FAUNAS OF THE MEEKOCERAS ZONE

The Meekoceras fauna of Madagascar.—During the past year Dr. H. Douvillé[2] has announced the discovery of the *Meekoceras* fauna on Madagascar; with *Meekoceras* cf. *gracilitatis*, *Flemingites*, *Cordillerites*, and *Lecanites*, all closely allied to species in the American fauna. This argues for a connection during this epoch between the Great Basin Sea and the Indian Ocean. Madagascar and the Great Basin of western America are almost exactly opposite each other on the globe, and the distance would be about twelve thousand miles by a great circle. From the Great Basin to Madagascar around the old shore line of the North Pacific, and then down the Asiatic coast and around the old shore line of the ancient Australasian land-mass, would be about twenty-one thousand miles. But if

[1] Published by permission of the Director of the U.S. Geological Survey.

[2] *Compt. rendus. Acad. Sci.*, 1910, p. 210; and *Bull. Soc. géol. France*, 4e sér., Tome X, pp. 125.

there was an arm of the sea connecting the Indian Tethys with the southern Indian Ocean the distance would not be more than fourteen thousand miles. This geosyncline, or arm of the sea, did exist in Jurassic time, and it is probable that the occurrence of the Pacific-Asiatic fauna of the *Meekoceras* zone in Madagascar marks the birth of the Indian Ocean.

The Meekoceras fauna of the Indian Archipelago.—Dr. J. Wanner[1] has recently described the *Meekoceras* fauna of the Island of Timor in the Indian Archipelago, listing from there; *Meekoceras*, *Flemingites*, and *Pseudosageceras multilobatum*, with species all closely related to forms already known in India and in the Great Basin Sea, showing the existence of the Tethys during this epoch.

The Meekoceras fauna in India and Siberia.—The *Meekoceras* fauna of India has long been known, but a recent work by Diener and von Krafft[2] has added greatly to our knowledge, and has made possible exact comparisons and correlations of faunas. In this monograph Diener and von Krafft bring out very clearly the intimate relations existing between the Indian, the Siberian, and the western American faunas of this zone.

The Arctic Meekoceras faunas.—The *Posidonomya* beds of Spitzbergen have long passed as Middle Triassic, but they contain several species almost identical with forms in the *Meekoceras* beds of Idaho. They were described as "*Ceratites*" but there can be no doubt that "*Ceratites*" *costatus* belongs to *Flemingites*, and that "*Ceratites*" *polaris* and *C. whitei* belong to *Meekoceras*, very closely allied to *M. mushbachanum*, all typical of the Lower Triassic. This fauna must then be placed in the Brahmannic stage of the Lower Triassic. The only argument against this conclusion is the supposed occurrence in the Spitzbergen beds of a *Monophyllites* of Middle Triassic character. But this species is almost identical with *M. sphaerophyllus*, a group typical of the higher Muschelkalk beds of Bosnia, India, and Nevada, and the specimen probably came out of the *Daonella* beds of Spitzbergen, which do contain an upper Muschelkalk fauna. Such a

[1] *Centralblatt für Min. Geol. und Pal.* 1909, pp. 137–47; 1910, p. 736; *Neues Jahrb. für Min.* etc., 1911, Beilage Bd. No. XXXII, pp. 177–96.

[2] "Lower Triassic Cephalopoda from Spiti, Malla Johar, and Byans," *Pal. Indica.*, Ser. XV, Vol. VI, No. 1, 1909.

confusion of species might easily happen, under the conditions of collecting in that region.

The *Meekoceras* fauna of southwestern Siberia, Thibet, and India is too well known to need further discussion here. It contains this same assemblage of genera already mentioned, mostly near allies of the genus *Meekoceras*. This fauna has been described in numerous monographs by Waagen, Diener, Noetling, and Griesbach, and has become the standard of comparison for the rest of the world.

The Meekoceras fauna in western America.—In southeastern Idaho and in the Inyo Mountains of California the *Meekoceras* fauna has been described in the works of C. A. White, Alpheus Hyatt, and the writer, with a wealth of genera similar to those of Asia, and some few identical species. The most characteristic genera are: *Meekoceras*, *Aspidites*, *Flemingites*, *Hedenstroemia*, *Pseudosageceras*, *Cordillerites*, *Lanceolites*, *Xenodiscus*, *Nannites*, *Inyoites*, *Owenites*, and *Lecanites*.

The writer has recently found this same fauna near the ranch of Henry Phelan, in White Pine County in eastern Nevada, about seventy miles south of Wells station on the Central Pacific Railroad. This locality is about half-way between the localities in California and Idaho, and distant over three hundred miles from each. The following is a preliminary list of the species identified: *Meekoceras gracilitatis*, *M.* cf. *mushbachanum*, *M.* cf. *radiosum* Waagen, *Proptychites* cf. *Walcotti*, *Lanceolites* sp. nov., *Pseudosageceras intermontanum*, *Aspenites acutus*, *Inyoites oweni*, *Owenites* cf. *koeneni*, *Nannites dieneri*, *Paranannites* cf. *aspenensis*, *Ophiceras* sp. nov., *Xenodiscus* cf. *whiteanus* Waagen, *X.* cf. *nivalis* Diener, *Pseudomonotis* cf. *idahoensis*.

By a comparison with lists from Idaho and from California it will be seen that the affinities with the latter are closer than with Idaho, although the two provinces were intimately related, and the new locality in Nevada gives a perfect connecting link, as it should, from its geographic position.

The *Meekoceras* fauna is one of the most distinctive and widely defined interregional correlation zones in the world, being known from Spitzbergen on the north, through the equatorial region of

Timor, to Madagascar on the south; from India on the west, through the Tethys to southeastern Siberia, to the Great Basin Sea of western America. It is not known in the Mediterranean region, nor in South America, Africa, nor Australia. Its genera and species are closely related in all the regions mentioned, so that an intimate connection between those regions is certain. It would seem probable that at this time there was a barrier between the Poseidon Ocean and the Pacific, and between the Mediterranean and the Oriental Tethys. It is certain that there was a connection between the North Pacific and the Arctic Ocean, and that the Great Basin Sea opened into the North Pacific. It is equally certain that the North Pacific was connected with the Oriental Tethys through the Archipelago north of Australia, this narrow sea extending westward to India, and southward in a great geosyncline to Madagascar.

The distribution of the *Meekoceras* fauna rivals, and even surpasses, that of the *Arietites* fauna of the Lias. Truly, this speaks for remarkably uniform conditions in the sea of that time, but whether warm, temperate, or cold we cannot say, for we know nothing of the corals in the sea, nor of the land plants, which might give us some indication of the temperature.

THE TIROLITES FAUNA

The *Tirolites* fauna has long been known in the Mediterranean region, where it was formerly supposed to be the only one. It is especially characterized by the abundance of the genus *Tirolites*, which until recently was supposed to be confined to this region.

In recent years the writer[1] has described the occurrence of the *Tirolites* fauna in southeastern Idaho, with *Tirolites* cf. *cassianus* Quenstedt, *T.* cf. *haueri* Mojsisovics, *T.* cf. *smiriagini* Mojsisovics, *Dalmatites* cf. *morlaccus* Kittl, *Dinarites* sp. nov., etc.

This fauna is of decidedly Mediterranean character, and unlike anything known elsewhere, though Diener and von Krafft have described a single species of *Tirolites* from the Lower Triassic of India. The close relationship of the *Tirolites* fauna of Idaho with

[1] Festschrift—Adolf von Koenen (1907), *The Stratigraphy of the Western American Trias*, 398–99.

that of the Alpine Province of the Mediterranean region shows an intimate connection, not through the Oriental Tethys, but rather through the Poseidon Ocean. At that time there was no barrier between the Caribbean Sea and the Pacific, but the portal between the Pacific and the Oriental Tethys was probably closed, as was also the portal between the Oriental Tethys and the Mediterranean.

THE COLUMBITES FAUNA

The *Columbites* fauna of Idaho was described by Alpheus Hyatt and the writer,[1] from a single locality near the town of Paris. It is characterized by the abundance of the genus *Columbites*, a member of the family *Tropitidae*, *Ophiceras*, *Xenodiscus*, *Pseudosageceras*, with a few species that have survived from the older *Meekoceras* fauna. There was also found in it a single species of *Tirolites* near *T. seminudus* Mojsisovics, a survivor from the underlying *Tirolites* zone. At the time when this fauna was described it was supposed to be unique, nothing like it being known anywhere, though the writer recognized its kinship to the Olenek fauna of northern Siberia.

The section at Paris Canyon is very instructive, for there is exposed the entire sequence of the Lower Triassic. At the base are the *Meekoceras* beds—yellowish-gray limestones—about twenty-five feet thick, with *Meekoceras gracilitatis*, *Flemingites cirratus*, *Ussuria waageni*, *Nannites dieneri*, *Pseudosageceras intermontanum*, *Lanceolites compactus*, and many other forms characteristic of this horizon.

About two hundred and fifty feet higher up in the section are the *Tirolites* beds—gray calcareous shales—with the forms listed under the *Tirolites* fauna. About twenty-five feet higher is a thin bed of brownish bituminous limestone, in which the *Columbites* fauna was found, containing *Columbites parisianus*, several other species of the same genus, *Xenaspis*, *Xenodiscus*, *Celtites*, *Pseudharpoceras*, *Ophiceras*, *Meekoceras*, and *Pseudosageceras intermontanum*, besides a *Tirolites* near *T. seminudus* Mojsisovics. The *Meekoceras* and *Pseudosageceras* are survivors from the *Meekoceras* beds, while the *Tirolites* has lived over from the preceding *Tirolites* fauna.

This *Columbites* fauna in Idaho is very important in settling the

[1] *Professional Papers U.S. Geol. Survey No. 50*, 1905.

age of certain disputed beds thousands of miles away, occurring, as it does, associated with survivors from the underlying beds in the same section, and above both the *Tirolites* and the *Meekoceras* faunas in the same canyon. In the first place, this proves the Lower Triassic age of the *Meekoceras* beds, if further proof were needed, since several abundant and characteristic species range through the entire section, and since the *Tirolites* beds, only a few feet below, contain a fauna virtually identical with that of the classic Campil beds, the type of the marine Lower Triassic of the Mediterranean region. But the *Columbites* beds belong to a horizon higher than any yet found to be fossiliferous in the original Mediterranean section, that is, to the barren upper Campil beds, as will be shown later in the discussion of the Albanian occurrence of this formation.

The Olenek beds of northern Siberia have long passed as the equivalents of the upper part of the Lower Triassic, but without any definite proof. Now since the faunas of the Olenek beds of Siberia and of the *Columbites* beds of Idaho are so closely related, and the stratigraphic position of the latter is positively known, the long-desired proof is brought. The Olenek beds are Lower Triassic, but younger than the *Tirolites* beds of the Mediterranean region.

Further proof of the validity of these conclusions has recently been published by Dr. G. von Arthaber,[1] from Albania on the Balkan Peninsula. Dr. von Arthaber describes from that region an assemblage of genera very like that of the *Columbites* fauna of Idaho, with some species that he considers identical; they include: *Columbites*, *Meekoceras*, *Celtites*, *Hedenstroemia*, *Sageceras*, *Pseudosageceras*, *Nannites*, *Lecanites*, *Pronorites*, *Tirolites*, *Parapopanoceras*, etc. According to Dr. von Arthaber, *Pseudosageceras multilobatum* Noetling is the same as *P. intermontanum* H. and S., and *Nannites heberti* is identical with *N. dieneri* H. and S., and those two species are also known in the *Hedenstroemia* beds of India. I do not agree with him as to the Albanian species of *Pseudosageceras*, which seems to me to be identical with *P. intermonta-*

[1] "Ueber die Entdeckung von Untertrias in Albanien und ihre faunistische Bewertung," *Mittheil. Geol. Gesell. Wien*, I (1908), 245–89; and "Ueber neue Funde in der Untertrias von Albanien," *ibid.*, II, 1909, 227–34.

num, but not with *P. multilobatum*. In fact, it does not seem to me that any species of the Albanian fauna is identical with any from India, but that the relationship is nearer to the boreal Olenek fauna and to the American *Columbites* fauna. This seems to the writer to be a boreal fauna that came down to the Mediterranean on one side, and to Idaho on the other. We know such a boreal invasion, in the Upper Triassic, when the *Pseudomonotis subcircularis* fauna came down to the Crimea on the one side, and to California on the other. It is probable that in Triassic time there was a depression connecting the Mediterranean with the Arctic Sea, and that periodic migrations came southward through this. In Idaho it was undoubtedly such an incursion. It is possible, however, that the appearance of the *Columbites* fauna in Mediterranean waters may be the beginning of an Indian immigration, which culminated in the lower part of the Middle Triassic as recorded by the Indian fauna of the Gulf of Ismid in Asia Minor.

To sum up, it seems probable that during the Brahmannic epoch of the Lower Triassic the Indian Region was the distributing point for the *Meekoceras* fauna, and that the swarming inhabitants of that sea migrated outward in all directions where marine connections permitted, reaching Spitzbergen on the north, Madagascar on the south, and the Great Basin Sea on the east; but that there was no connection between the Oriental and the Mediterranean divisions of the Tethys, nor between the Mediterranean-Poseidon waters and the Pacific.

During the *Tirolites* epoch a connection was opened between the Mediterranean-Poseidon Ocean and the Great Basin, but the latter body of water was not connected closely with the Arctic Ocean.

During the *Columbites* epoch the center of distribution of the known faunas seems to have been the Boreal Sea, from which migrations came southward to the border of the Mediterranean region, probably through Asia, and down to the Great Basin through the northern passage. There was probably no direct connection between the Poseidon-Mediterranean Ocean and the Pacific, nor any very close union between the eastern and the western divisions of the Tethys.

These periodic shiftings of ancient geographic relations do not show shiftings of the ancient seas, but rather prove the periodic opening and closing of the gateways connecting them. These gateways, or portals, are areas of depression on or between continental masses, and lie in regions of permanent instability of the earth's crust, where mountain-building, and the accompanying volcanic and earthquake disturbances have been prevalent. Some of these ancient portals are temporarily open now, on account of recent subsidence, as, for instance, the Bering Strait; another has been recently opened, by the activity of man—the Suez Canal. And the Panama Canal will restore a connection between the Atlantic and Pacific, which is temporarily closed on account of recent elevation in that region. One of these portals, that connecting the Oriental Tethys with the southern waters, has expanded into the Indian Ocean. Others of the ancient portals are now concealed in continental masses, and their very existence would not be suspected without studies in interregional relationships of faunas.

PANTYLUS CORDATUS COPE

MAURICE G. MEHL
The University of Chicago

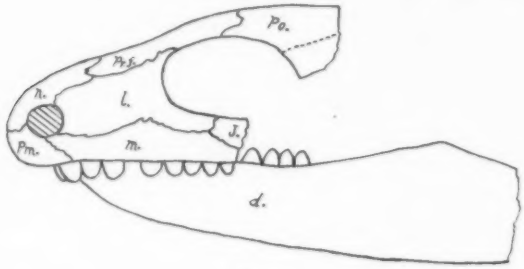
E. C. Case, in his recently published revision of the Cotylosauria of North America, has given to the genus *Pantylus* Cope the rank of a suborder, the Pantylosauria. Nothing is known of the genus aside from the skull and even that is more or less incomplete in the two hitherto known specimens. *Pantylus* is peculiar in so many respects that any new facts concerning it are of interest. It is for this reason that the writer here describes another specimen which, though incomplete, adds some additional facts of importance especially as regards the dentition.

The specimen herein described was collected by Mr. P. C. Miller, of the University of Chicago expedition of 1908, from the Lower or Wichita division of the Red Beds of Baylor County, Texas, near the Big Wichita River. It consists of the anterior part of the cranium, as in the type, the anterior part of the left mandibular ramus, and a nearly complete right ramus. Unfortunately the posterior part of the skull is missing, but it is fairly complete from a point a short distance back of the posterior border of the orbits to the muzzle. A little of the posterior end of the right ramus is missing, but nearly the entire length is represented and the dentition is complete.

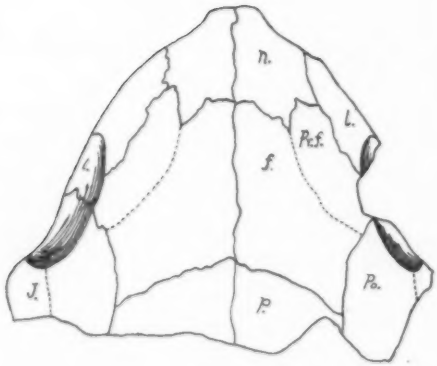
As shown in the appended table of comparison, the specimen is somewhat larger than the type. Although the posterior part of the skull is missing, its width must have been greater than the type, for the spread of the mandibular rami is at least 92 mm. Fig. 1*b* shows the anterior part of the cranium with most of the sutures indicated. Those between the premaxillaries, maxillaries, lachrymals, nasals, and parietals are distinct.

There is no trace of the sutures between the postfrontals and the prefrontals. In fact, there are but slight traces of the suture between the frontals and prefrontals, and this suture, with that

between the jugal and postorbital, is for this reason indicated by dotted lines. A comparison with Cope's figure[1] will bring out a few differences. The maxillary bone is here shown as taking part



1a



1b

FIG. 1.—*Pantylus cordatus* Cope. 1*a*, side view of skull with jaw attached. 1*b*, top of skull showing sutures. Figures natural size.

in the orbit. As indicated in Fig. 1*a*, the maxillary enters slightly into the external nares, but is excluded from the orbit by the lachrymal and jugal which unite in the inferior border of the orbit about

[1] *Trans. Am. Phil. Soc.*, XVII (1892) 25, Pl. 1, Fig. 4.

midway. This is essentially as Case has figured it.[1] The lachrymal extends back from the nares in a broad triangle and forms the entire anterior border of the orbit. It forms the floor of the front half of the eye cavity and extends inward nearly to the nares.

The arrangement of the palate bones, so far as one can make it out, is much the same as that in *Captorhinus*. The premaxillary is probably short and does not enter very largely into the internal nares. The prevomers are rather broad and well developed. They lie along the inner side of, and extend nearly to the posterior border of, the nares. The pterygoids, of which the posterior end is missing on both sides, send forward rather broad processes that converge in a gentle curve and meet at a point a little back of the posterior border of the orbits. From this point they extend forward, gradually narrowing and separating the prevomers fully half their length. In cross-section the pterygoids are angular, one side lying in the plane of the palate, the other extending vertically nearly to the cranial roof. Back of the nares and forming their posterior border lie the broad, platelike palatines. They extend inward toward the median line, underlying the pterygoids and extending upward along the inner angle of these bones. The transverse bones, if present, are indistinguishable.

Dentition.—While the upper dentition is probably not complete in this specimen, the essential features are readily made out. The premaxillary bears two teeth, the first of which is the larger, 4 mm. or more in diameter. The maxillary bears eight teeth and probably about four more of the posterior ones are broken away. The first two of these exceed those following in diameter and height, the second being the larger of the two and measuring but little less than the first premaxillary tooth. The remaining maxillary teeth are slightly oval in cross-section rather than circular and are sub-equal in diameter and height, these measurements being about 2 mm. and 2.5 mm. respectively. The prevomer region of the palate was exposed from above as the matrix below was very hard and was protected by the anterior part of the mandible. Hence it cannot be said with certainty whether the prevomers bear teeth or not, but in all probability they do. On each palatine there is a large,

[1] *Publication No. 145*, Carnegie Institution of Washington, p. 114, Fig. 52*c*.

rather well-defined pad of teeth, which in shape and size corresponds to a similar pad on the splenial. Measurements show that these two pads are exactly opposed posteriorly. Anteriorly, however, the lower pad apparently underlies the posterior part of the narial opening. The teeth of the palate group vary considerably in size and basal cross-section, apparently with no definite arrangement as to height or diameter. Most of the larger teeth, however, are disposed anteriorly although some of the smallest crowd closely on the posterior border of the nares. These palatine teeth are the same shortly conic, obtuse form as those of the lower dentition. They vary from 1.5 mm. to 3 mm. in height and from 1 mm. to 4 mm. in diameter. On the palatines one is able to make out about twenty teeth. The pterygoids are studded with irregularly placed, small, conical teeth, some fourteen of which are shown in the figure. These vary somewhat in size, though all are small, some being little more than mere points. Apparently all are hollow as are the other teeth.

Mandible.—The nature of the lower jaw is given by E. C. Case in his revision of the Cotylosauria (p. 114). Fig. 2*b* shows a cross-section of the right ramus at the third tooth from the last in the dentary series. The suture above separating the dentary and the splenial is readily made out, as is that intersecting the broad lower surface of the ramus. It is the upper, inner element of the mandible that bears the pad of teeth referred to above. Clearly this is the splenial. Besides these sutures which are easily seen, it is possible that two other elements are shown as indicated by the dotted lines; one with an angular cross-section on the lower, inferior angle of the ramus, and a thin platelike one on the inferior surface. Immediately above the dentary, within the central cavity, lies a thin plate of bone that is apparently no part of the dentary or the element joining it. The central cavity is confluent with the large orifice immediately posterior to the splenial group of teeth, as shown in Fig. 2*a*. From the dentary foramen a well-marked suture runs up and forward to the inner, anterior margin of the Meckelian orifice. Further than this, one is unable to make out the sutures with any degree of certainty. Like the other dimensions of the specimen, those of the lower jaw are greater than in the type specimen as shown in the table.

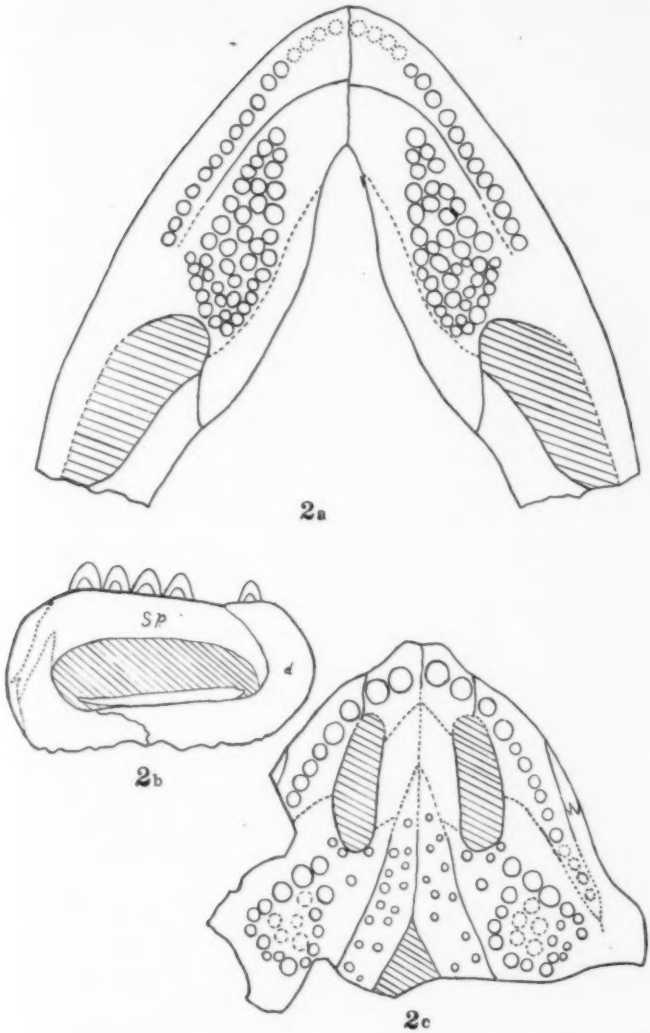


FIG 2.—*Pantylus cordatus* Cope. *2a*, lower jaw showing dentition. Natural size. *2b*, cross-section of right ramus at the third tooth from the last in the dentary series. Figure twice natural size. *2c*, palate view showing dentition. Natural size.

The greatest interest of the specimen probably lies in its mandibular dentition. Beyond a doubt the larger number of teeth are on the splenial bone instead of the dentary. Unfortunately the crowns of most of the teeth of the mandible were destroyed in the separation of the rami of the skull. One is able nevertheless to make out the arrangement of all the teeth except for a short distance on the anterior border. This space is well beyond the termination of a regular, definitely outlined inner pad of teeth, however, and most likely only the outer row is continued forward. Judging from the size of the teeth exposed in the outer row, there are four teeth hidden in this anterior part of each ramus by the matrix of the projecting muzzle. As suggested above, the teeth are arranged in two groups, an outer row of sixteen teeth, the posterior twelve of which are shown, and an inner pad or series. In the outer row they apparently do not vary greatly in cross-section. As to any variation in height of crown I am unable to say. This series, I am confident, comprises the only teeth on the dentary. The inner series is arranged in a pattern of regular shape. The outline of this pattern is formed by a band of twenty-five teeth which become progressively smaller posteriorly from nearly 3 mm. in cross-section at the anterior border to 1.5 mm. at the posterior side. Within this peripheral band are fifteen irregularly disposed teeth. In cross-section these range from 4 mm. to 2 mm., the larger being disposed anteriorly. It is impossible to determine the height of the crowns of this inner series but it is certain that some of them were higher than the regularly placed peripheral group. It is interesting to note that while the teeth of the inner series show a circular section midway between the base and the apex, the base often shows a polygonal cross-section and here only small interspaces are left between the teeth.

In Cope's description of *P. coicodus*, the second species of this genus, the chief distinguishing features are found in the teeth. They have a pointed apex like the grass seed *Coix lachroma*, while those of *P. cordatus* are obtuse. *P. coicodus* also has "partially pleurodont" teeth with a swollen crown on a shanklike base. Case suggests that the obtuse tooth of *P. cordatus* is simply that of *P. coicodus* with the pointed apex worn down and that the two species

are not distinct. In the specimen here described the teeth do not appear to be greatly worn and they probably never had the pointed apex. The shanklike base is also wanting and the teeth are distinctly acrodont. For these reasons I believe that *P. coicodus* and *P. cordatus* are distinct species. And, furthermore, if Cope was correct in his statement that *P. coicodus* has a partially pleurodont dentition, the differences seem to be greater than specific.

The dentition would suggest peculiar food habits for the animal. The lack of sharp teeth certainly indicates that its food did not require cutting. In all probability the dental armature was an adaptation for the crushing of shells of gastropods and other molluscs.

A COMPARISON OF MEASUREMENTS

	Type Specimen	Described Specimen
Length of axis of cranium to line connecting anterior border of orbits	0.018 m.	0.020 m.
Inter-orbital width	0.032	0.040
Longitudinal diameter of orbits	0.016	0.021
Length from orbit to nostril	0.015	0.018
Height of crown of large maxillary tooth	0.0045	0.003
Width of mandibular ramus below at middle	0.020	0.027
Length of part of ramus preserved	.....	0.084
Spread of rami at greatest length	.....	0.092
Width of cranium at line connecting posterior border of quadrates	0.077	.....

NOTES ON TERTIARY DEPOSITS NEAR COALINGA OIL FIELD AND THEIR STRATIGRAPHIC RELATIONS WITH THE UPPER CRETACEOUS

E. T. DUMBLE
Consulting Geologist Southern Pacific Company

The work of the California division of the geological department of the Southern Pacific Company during the spring of 1910 was devoted in part to the differentiation and careful definition of the oil-bearing formations of the Coalinga district and the area lying north of it and the mapping of the surface exposures of each as accurately as conditions would permit. Two field parties were engaged in this work, one of them comprising Mr. J. A. Taff, assisted by Mr. B. L. Cunningham, and the other Mr. F. M. Anderson, assisted by Messrs. G. C. Gester and E. A. Hardy. The work begun here is being extended to cover the west side of the San Joaquin Valley. As soon as the collections and field data have been properly studied, it is hoped that papers may be published by these geologists giving the geological details fully, but, since such publications may be delayed, I have arranged the following statement of some of the results of the early work, based on their preliminary reports and maps.

PREVIOUS WORK

The first two publications based directly upon the work of this department in this area were those by Mr. Frank M. Anderson, entitled "A Stratigraphic Study in the Mount Diablo Range of California,"[1] in 1905, and "A Further Stratigraphic Study in the Mount Diablo Range of California,"[2] in 1908. Prior to our work, we have only the reports of Mr. W. L. Watts in *Bulletins Nos. 3* and *19* of the California State Mining Bureau and the paper of Mr. George H. Eldridge in *Bulletin No. 213* of the United States

[1] *Proc. California Acad. Sci.*, 3d series, Geology, II (1905), 156–248.

[2] *Ibid.*, 4th series, Geology, III (1908), 1–40.

Geological Survey. Later publications on the area are those of Messrs. Arnold and Anderson in *Bulletins Nos. 357, 396,* and *398* of the United States Geological Survey.

A careful study of these publications indicates that no one has been able clearly to differentiate the basal beds of the Tertiary from the upper beds of the Cretaceous, and that the parting as drawn was purely suppositional. The Tejon was the only member of the Eocene positively identified, although Mr. Anderson suggests the possible Martinez age of some lower beds.

In the Neocene, the different divisions were fairly well established and while the Monterey or lower middle Miocene fauna seemed lacking, the sediment is probably represented by a peculiar formation called the Big Blue and the equivalency of the two was suggested.

THE CRETACEOUS-TERTIARY CONTACT

Through much of this territory the uppermost Cretaceous is represented by shales and the basal Tertiary is also shaly in character. This fact has made it difficult to clearly distinguish the one from the other or to mark their parting. In the earlier publications it was supposed that there was no appreciable break in the sedimentation of the two periods, and that there was also an overlapping of faunas. This latter supposition was disproved by the work of Messrs. Stanton, Merriam, and Weaver in their studies of the region north of Mount Diablo, and we now have also conclusive proof of great stratigraphic breaks, not only between the Cretaceous and the Eocene, but also between the formation to which these basal Eocene beds belong and the overlying Tejon, which was originally supposed to represent practically the entire Eocene of the California section.

The evidence of the stratigraphic break between the Cretaceous and Eocene is somewhat more clearly shown at a point outside this territory than has yet been proven within it, and our study of this section enables us to trace the parting in the territory under discussion.

Some six or seven miles southwest of Antioch and in the eastern foothills of Mount Diablo, there is a short canyon where a slight sipe of oil was found, from which circumstance it was given the

name of Oil Canyon. A few years ago, two or three wells were sunk here in a search for oil, but failed to develop it. The north bank of this canyon gives us very distinctly the relations of the Cretaceous and Eocene.

The Chico is represented through the greater part of its exposure by a purple shale identical in appearance with that of the Coalinga region. Through a part of this shale there are beds of concretionary clayey limestone with ammonites and other Chico forms. Above this, the concretions, scattered irregularly through the shale, take the form of a very fine-grained blue limestone which weathers perfectly white. Toward the eastern end of the exposure this purple shale is overlain by a gray sandstone weathering brown. It is rather coarse grained as a whole, even conglomeratic in places, and is quite massive in structure. It carries limy concretions which contain fragments of Inocerami.

The lowest Eocene or Martinez deposit begins with a brown sand and sandy shale, more or less glauconitic, with limy concretions carrying a Martinez fauna. Higher in the section the shaly nature of the beds becomes more pronounced and they carry concretionary nodules of limestone and ironstone. Near the center of the section, as exposed here, there is a band of coarse red sandstone with some greensand, green mica, and casts of fossils. It is only a few feet in thickness and is succeeded by brown shales which carry more and more clay toward the top and more numerous and larger concretions of clay-ironstone, and lime.

At the west end of this section, opposite the head of Oil Canyon, the Martinez sandy shales rest on the Chico purple shale immediately above the band of the clayey limestone with ammonites. Going eastward a mile, higher and higher beds of the Chico shale appear under the Martinez until, at a horizon fully 125 feet stratigraphically above the first observed contact, the point of the sandstone wedge comes in and thickens until there is a body of at least 80 feet of it exposed below the Martinez.

While the exact point of contact is difficult to place where the two shale beds come together, it is entirely possible to say within a few feet of such contact, "This is Chico," or "This is Martinez," from their dissimilarity. On the sandstone, however, the contact

is sharply defined. There are numerous borings in the top of the Chico sandstone which are filled with the fine gravel and sand of the Martinez, and covering the surface is a layer of glauconitic sandy material with imprints of small shells, which is the base of the Martinez. This grades upward into the sands and sandy shales with concretions and nests of Martinez fossils.

With this section in mind, the tracing of the contact in the area north of Coalinga is not so difficult. The top of the Chico comprises purple shales and concretionary sands, and the base of the Martinez, while of much more argillaceous character than at Oil Canyon, is yet distinct.

MARTINEZ FORMATION

To Messrs. Stanton, Merriam, Weaver, and Dickerson[1] is due the credit of demonstrating in the Mount Diablo region the existence below the Tejon of a series of beds of Eocene age, which is clearly distinguishable from that terrane by its characteristic fauna and unconformable relationship. This has been named the Martinez, but only meager accounts of its stratigraphy are available and its existence was recognized at only a few localities.

Our work now proves that this lower member of the Eocene is of very considerable extent southward on the west side of San Joaquin Valley; that it consists of three or more clearly defined members, and that, in addition to the unconformity already described between it and the Cretaceous, there also exists a decided unconformity between it and the overlying Tejon.

The Martinez is well developed in Townships 17 and 18 South, Ranges 13 and 14 East, in the Salt Creek-Cantua region, and comprises a basal bed of chocolate shales with glauconitic sands overlain by yellow sands and conglomerates and these overlain in turn by other chocolate shales. The generalized section of the Martinez in this particular area may be stated as follows:

[1] T. W. Stanton, "The Faunal Relations of the Eocene and Upper Cretaceous on the Pacific Coast," *17th Rep. U.S. Geol. Survey* (1895–96), pp. 1011–60.

J. C. Merriam, "The Geologic Relations of the Martinez Group of California at the Typical Locality," *Jour. Geol.*, V (1897), 767–75.

C. E. Weaver, "Contribution to the Paleontology of the Martinez Group," *Univ. Calif. Publ. Bull. Dept. Geol.*, IV (1905), 101–23.

Roy E. Dickinson, "Stratigraphic and Faunal Relations of the Martinez Formation to the Chico and Tejon North of Mt. Diablo," *Univ. Calif. Publ. Bull. Dept. Geol.*, VI (1911), 171–77.

	ft.	
3. Upper chocolate shales, comprising bluish shales at top, grading down into chocolate or brown shales which weather to clays.		
These rest upon other chocolate shales which become sandier toward bottom. These shales vary in thickness	600–900	
2. Yellow sand and conglomerate.		
Bluish sandy shales and thin sandstone, variable in thickness	200	
Massive yellow sandstone with large dark brown segregations and concretions and some layers of bluish sandy shale	300	
Fine sand with local beds of conglomerate interbedded with blue and brown shales; a considerable amount of glauconitic material at base	300	
1. Lower chocolate shales.		
Beds of chocolate and brown shale with small ferruginous and limy concretions and layers of glauconitic sand	1,000	
		2,700

Mr. Anderson reports the following forms collected from the top of the lower chocolate shales at a locality on Salt Creek in the SW $\frac{1}{4}$ of NW $\frac{1}{4}$ Section 25, Twp. 18 S., R. 14 E.:

Corbula horni Gabb
Meretrix fragilis Gabb
Leda gabbi Conrad
Margaritella angulata? Gabb
Helicaulax costata Gabb
Ataphrus crassus? Gabb
Neverita globosa Gabb
Arca horni Gabb
Architectonica horni Gabb
Rimella canalifera Gabb
Bulla horni Gabb
Nucula truncata Gabb
Modiola ornata Gabb
Pectunculus sp.
Discohelix californica Weaver
Turritella pachecoensis Stanton
Cucullea matthewsoni Gabb
Arca biloba Weaver
Dentalium sp.
Cylichna costata Gabb
Barbatia morsei Gabb
Spiroglyphus tejonensis Arnold
Pleurotoma fresnoensis Arnold
Corbula paralis Gabb
Venericardia alticosta Gabb
Numulites
Shark teeth

While a number of these forms are common to the Tejon and Martinez, there are several that are characteristic of the Martinez, and this, taken with the relation of these beds to the overlying Tejon, makes it necessary to refer them to the Martinez.

The greatest surface exposure of these beds in this area is found in Twp. 17 S., R. 13 E., where except for a band of Cretaceous along the south line they form the surface rocks for the entire southern half of the township. The exposure of the lower shale is only a half to three-quarters of a mile in width and the upper shale occupies a similar belt, but the yellow sandstone member has an average breadth of exposure of nearly two miles. On the eastern line of this township this is narrowed to half a mile and the three members cross the north line of Twp. 18 S., R. 14 E., with a total width of less than two miles. This is again narrowed toward the southeast until in Section 23 of this township the upper brown shale and the greater part of the yellow sand has been removed by pre-Tejon erosion, and, south of that point, so far as it occurs, the Martinez is represented beneath the Tejon only by the basal shale with a thin band of yellow sand overlying it through a part of the area.

TEJON FORMATION

The series of sediments here assigned to the Tejon admit of separation into two distinct members; the lower of white sand and conglomerate carrying a fauna in all respects identical with that of the original Tejon locality, and an upper member of white shale which is not so fossiliferous and which, as has been suggested by different investigators in this area, may in part or as a whole represent the Oligocene.

The general section of the Salt Creek-Cantua region is as follows:

5. White shale.		
White fissile organic shales, containing fish scales, teeth, foraminifera, etc.	FT. 500	
Lenses of fine brown sand.		
White shale with local thin sandy strata	1,000	
Local friable sand	0–30	
Pink to white shale	200	
Bluish sandy shales grading up into pink shales	40	
		1,770

4. White sandstone and conglomerate.

Yellowish to white, usually fine sand	100–160
White massive sandstone and conglomerate with whitish shale inclusions at the base	20–40
	200

In this portion of the field the base of the Tejon is a fossiliferous conglomerate and sandstone which shows distinct unconformity with the underlying Martinez. Thus, on the east line of Section 17, Twp. 19 S., R. 15 E., the base of the conglomerate is upon an oxidized zone and the massive sandy shale immediately below the conglomerate is cut by numerous burrows that appear to have been made by crustaceans, in some cases extending down to a depth of three feet. These burrow holes have been filled with ferruginous sand and gravel conglomerates that are connected directly with the overlying conglomerate. To the northwest in Twp. 17 S., R. 13 E., where the conglomerate rests upon the upper shale of the Martinez, it contains shale inclusions at the base.

Here, as elsewhere, the Tejon carries coal locally. These coal seams occur near the base and as thin stringers higher in the section, but in this area they have not proven to be of economic value. It is interesting to note that the coal north of the Cantua occurs above the conglomerate, which we here make the base of the Tejon, while west of Coalinga it occurs below a similar conglomerate. At the Oil Canyon locality, described under the Martinez, the Tejon beds are coal bearing only in their upper portion, that is, from 250 to 300 feet below the top, while below the coal-bearing beds there is probably a thickness of 600 feet of shale before the heavy conglomerate, which there marks the base of the formation, is reached. For this reason, it would seem that either this member of the Tejon has much decreased in thickness or that only the upper portion of the beds as seen at Oil Canyon are represented there.

While the exposures of the upper white shale are excellent through Coalinga–Salt Creek–Cantua area, the few fossils obtained during this examination do not give any more definite grounds for determining its age than those before known. It apparently succeeds the lower member of the Tejon without unconformity and is highly unconformable with the succeeding Vaqueros beds of Lower Miocene age.

MIOCENE

The character and divisions of the Miocene in this region have been quite fully described in the publications referred to and especially by Messrs. Arnold and Anderson in the Bulletins of the United States Geological Survey. The divisions present in this area are as follows:

5. Etchegoin
4. Jacalitos
3. Santa Margarita
2. Monterey?
1. Vaqueros

1. VAQUEROS

The Vaqueros comprises all beds found between the Tejon and the Big Blue, the basal non-fossiliferous member of Santa Margarita of Arnold. It is predominatingly sandy, with conglomerate at base, and very fossiliferous as a whole. It lies with marked unconformity upon the Tejon. The basal unconformity which has been described and fully illustrated elsewhere is marked in Twp. 17 S., R. 14 E., by the absence of its lower beds, the upper portion resting directly on the Tejon white shale.

2. MONTEREY

The series of light-gray, fine-grained sand and clay that appear bluish when moistened, which lies between the Vaqueros and Santa Margarita, has been called the "Big Blue" and its possible Monterey age has been suggested by Arnold, who classed it tentatively with the Santa Margarita. It has a thickness of nearly 300 feet in the oil field, but appears to be somewhat thinner toward the northwest. It is clearly separated from the Vaqueros beds below and the Santa Margarita above.

In Twp. 17 S., R. 14 E., it occurs as bluish shales that in places are variegated reddish and yellow, succeeded by sandy bluish shales intermixed with gravel, having a total thickness of about 200 feet. The shales are unfossiliferous here as elsewhere, but are easily separable from the Santa Margarita, since the basal conglomerate of that formation contains a wealth of typical Santa Margarita fossils.

The stratigraphic position of the Big Blue north of Coalinga is

the representative, in part at least, of the Monterey in the Sunset-McKittrick field. At its most southern exposure in Section 29, Twp. 19 S., R. 15 E., just before it is lost under the overlapping Jacalitos, it appears as a white, apparently organic, silicious shale very similar in appearance to and in the same stratigraphic position as the shale of the Monterey where it emerges from this overlap in the southern part of the Coalinga field. That the Big Blue is the attenuated northern and more littoral representation of the Monterey is clearly evident.

SANTA MARGARITA

The base of this division of the Miocene in the Coalinga field is marked by the *Tamiosoma* zone and is overlain by sands and gravels with a total thickness of 600 feet. It is overlain unconformably by the later formations. These features continue northward but gradually the lower member grades into a remarkable conglomerate. On Salt Creek thick beds of heavy serpentine conglomerate occur in it and near the south edge of Twp. 17 S., R. 14 E., it becomes a variable deposit of coarse irregular serpentine breccia with beds of conglomerate, sands, and shale. The size of the material gradually decreases toward the northward along the outcrop and the fragments show greater wear. The beds contain the typical Santa Margarita fossils and are overlain by the sandy clays and gravel beds of its upper member.

JACALITOS AND ETCHEGOIN

The beds described under these names in the Coalinga field and supposedly separable there by the fossils contained in them continue northward, but generally without the fossils, so that it is difficult to separate the two in Twps. 18 N., R. 14 and 15 E., and 17 N., R. 13 and 14 E., and in fact to distinguish between them and the overlying Pliocene, the entire measures as exposed being a variable series of sandy clays, sands, and gravel beds aggregating 1,800 to 2,000 feet in thickness below the alluvial deposits to the east.

We were unable clearly to differentiate the Jacalitos and Etchegoin in the Coalinga region, since we found more than one Glycymeris zone in them, neither of which was mappable throughout

the field, and the Jacalitos-Etchegoin appears to be one progressive series overlapping far upon older rocks during a period of long-continued submergence.

RESULTS

Taking the results as a whole, it is probable that the most prominent and important geological fact brought to light is the continued and repeated oscillations of this part of the territory in Tertiary time, as opposed to the former idea of a practically uninterrupted sedimentation—proving that land areas existed here at the end of the Chico, the Tejon, and the Santa Margarita, and probably at the end of the Martinez and the Monterey.

The most extensive of these emergences was that between the Cretaceous and Tertiary; the next that between the Eocene and Miocene. Those between the Martinez and the Tejon and that at the end of the Monterey are not so definitely made out as yet, but there is good evidence of their existence.

The results of temporary oscillations occurring between or during these times are clearly apparent in the local unconformities existing in the various formations.

KAURI GUM MINING IN NEW ZEALAND

R. A. F. PENROSE, JR.

Several years ago, while on a trip to New Zealand, the writer had an opportunity to see something of what is known as kauri gum mining in that country. This industry consists of digging a resinous material which in bygone times has exuded from kauri trees and has become imbedded in the soil or subsoil, where it exists in a fossil condition, often in remarkably large quantities.

The kauri tree (*Agathis australis* Salisbury; *Dammara australis* Lambert) is characteristic of certain parts of New Zealand, though it is confined geographically to narrow limits, and is most abundant from Cape North southward to the Auckland peninsula, in about latitude 37° S., a distance of about 200 miles, where its gigantic size makes it the monarch of the forests. It is found but rarely south of latitude 38° S. It occurs most plentifully at rather low altitudes, and is rare at elevations of over 1,500 feet, though some trees have been found at 2,500 feet or more.[1]

The kauri tree has a straight, symmetrical trunk, rising frequently from eighty to one hundred feet in height and sometimes even as much as one hundred and twenty-five or one hundred and fifty feet. In diameter the full-grown tree varies from four to twelve feet, while in extreme cases it may measure twenty feet or more. The top of the tree is large and spreads out in heavy branches, while the trunk is comparatively smooth, with a gray bark which peels off and collects in heaps at the base of the tree. The kauri is not so large as some of the largest of the redwood (*Sequoia*) trees of California, but it occupies the same position of prominence in the New Zealand forests as do the latter on the western coast of the United States. Like the redwoods also it is very valuable for lumber, and many of the once magnificent forests have been cut down, but enough remain to attest to their former grandeur.

[1] T. Kirk, *The Forest Flora of New Zealand*, Wellington, N.Z. (1889), p. 150.

The so-called kauri gum is really a true resin and not a gum, but the latter term has become so generally used that it is here retained. The material is a solidified turpentine which exudes from the tree as a clear, transparent liquid and hardens rapidly on exposure to the air, assuming then a dull white or slightly yellowish appearance. It collects in large quantities on all parts of the trees, on the leaves, in masses on the branches and trunk, and throughout the bark. The heaps of bark that peel off and collect on the ground are saturated with it and become solidified. These fresh exudations, however, supply very little of the gum of commerce, most of the latter being a fossil gum which has come from the secretions of the kauri trees, and has accumulated in the soil of the forests, or in the clay or other formations below the soil. It is of a light or dark brown color, sometimes almost black, transparent to translucent in luster, generally more or less homogeneous in character, but sometimes including leaves, sticks, and insects. There is a popular impression in New Zealand that the fossil gum, through some process underground, has become purer than the fresh gum from the trees.

Kauri gum occurs both in regions now covered, or which have until recently been covered, with kauri forests, and also where no kauri trees have been known to grow in historic times, but where they existed in bygone ages and have been destroyed by fire, submergence, or other causes. In fact, the larger part of the kauri gum mined in New Zealand is derived from open country, called "gumfields," destitute of any considerable timber, while the old roots and other parts of trees found under the soil prove that kauri forests once existed there. It is generally supposed that in such cases the forests were destroyed by fire, and the burned character of the remains of the trees found with the gum lends some evidence to such an hypothesis. On the other hand, it has been suggested that a fire that would destroy a forest would also destroy such an inflammable material as the gum; but it must be remembered that the gum that had become buried in the soil would be more or less protected from fire. Moreover, the gum is so abundant that though much of it might be destroyed in a burning forest, yet much might escape.

In some places gum is found in the ground underlying forests in which few or no kauri trees occur, but its origin is shown by its occasional association with the remnants of kauri trees and by inclusions of leaves. In such instances the original kauri forests have long since disappeared and the present flora represents a subsequent growth. A remarkable case of this is described by Mr. Bagnall[1] at Turua, in New Zealand, where a forest composed mostly of

FIG. 1.—Kauri gum mining in New Zealand

kahikatea trees covers an area in which kauri gum is remarkably abundant. The gum is often more or less charred by heat and is associated with the remains of kauri trees. Mr. Bagnall thinks that some of the kahikatea trees in this region are not less than one thousand years old; and though parts of this forest may have existed before the kauri forest disappeared, yet we see in this case a suggestion that possibly gum deposits may sometimes be of

[1] L. J. Bagnall, "Notes on the Occurrence of Kauri-Gum in the Kahikatea Forest at Turua," *Trans. and Proceed., New Zealand Institute*, XXIX (1896), 412–13.

considerable age. In the locality in question, the gum was so abundant that as much as half a ton is said to have been taken from twelve square feet of ground.

Kauri gum also often occurs in swamps covering buried forests of kauri trees. New Zealand is a volcanic country, and frequent movements in the earth's crust occur, so that many kauri forests which once flourished on dry ground may become partly or wholly submerged, and may die and eventually be buried in swamps. The same result may occur where a lava flow obstructs a stream, forming a lake, which inundates a kauri forest. The lake may eventually be filled up, first becoming a swamp and then perhaps dry land again, inclosing the dead trees with the earthy accumulations. In either case accumulations of kauri gum may occur with the remains of the old forests.

Considerable kauri gum is also obtained in districts from which the kauri lumber has only recently been cut, while some is mined in the soil of still standing kauri forests, and a certain amount has been obtained by tapping the trees, but the practices of mining in living forests and of tapping have been largely prohibited as injurious to the trees.

The gum usually lies from a few inches to several feet in the soil or underlying clays and sands, though sometimes it is exposed on the surface. A depth of from two to four feet is common, and a greater depth is often encountered. On the dry uplands it is usually shallower than in the swamps, where it may sometimes be twelve feet or more in depth. It occurs in irregular lumps, from a few ounces to several pounds in weight, lumps of from ten to twelve pounds being not uncommon, and in rarer cases lumps of as much as fifty or one hundred pounds have been found. It is in very variable quantities in the soil, being in some places too scattered to work profitably, in others abundant.

In some places successive layers of clay or sand carrying gum have been found, one above the other and separated by barren layers. Sometimes there are three or four of these gum layers and they represent the sites of former kauri forests which have been successively destroyed. The gum from each forest accumulated in the soil and became more or less covered with earthy matter

which served to separate it from the next layer of gum formed from the next succeeding forest. In many gum fields, which were supposed to be exhausted when the top layer was worked out, the discovery of lower layers of gum has added fresh activity to the industry.

Kauri gum mining, or "gumming" as it is often called, is generally looked on as a rather poor occupation by the New Zealanders,

FIG. 2.—Kauri gum mining in New Zealand

and is often resorted to by people out of employment, or by miners who have not been successful in locating gold, silver, or other more permanent mines, and have taken to gum mining to get the means of continuing their prospecting. In this way the industry has afforded many a poor man funds to bridge over times of distress. There is in parts of New Zealand quite a large Austrian population, and these people have often been active in the gum industry, at times making considerable profits from it. The native Maoris resort to gum mining at idle times or when their crops fail. Gum mining is a simple process, and requires but little equipment, so

that it is peculiarly fitted for those operating without capital. A long pointed iron or steel rod, or spear, is used to explore the soil, and is stuck into the ground from spot to spot, until a lump of gum is located, which is then dug out by a spade. In swampy land, where the gum is in soft mud, a hook is sometimes used to pick it out. Where gum is very abundant the whole ground is sometimes dug up without "spearing" or "hooking."

FIG. 3.—Preparing kauri gum in New Zealand

Kauri gum mining began about 1847 and has continued ever since with varying annual productions. The production in 1856 was 1,440 tons; in 1893 it was 8,317 tons;[1] in 1903 it was 9,357 tons, and in 1910 it was 8,693[2] tons. Up to the end of 1906 the total product of kauri gum in New Zealand has been estimated at 275,319 tons, valued at £13,443,017.[3] The price of the gum has had

[1] *New Zealand Official Yearbook*, 1900.

[2] Statistics of the Dominion of New Zealand, 1910.

[3] J. M. Bell and E. deC. Clarke, "The Geology of the Whangaroa Subdivision, Hokianga Division," *New Zealand Geol. Survey* (1909), p. 96.

a tendency to rise since its early production, on account of its increased use and the limited supply. In recent years the price has ranged from £50 to £70 per ton for the higher grades of gum.

Kauri gum is used mostly in the manufacture of varnishes as a substitute for copal and mastic. Formerly it was shipped mostly to England and America, but later much of it began to be used locally in New Zealand. Some of the clear transparent or translucent varieties are used as a substitute for amber in the mouthpieces of pipes, cigar and cigarette holders, and a certain amount is used for carving small ornaments.

Reports are often heard of the approaching exhaustion of the gumfields, but the production still keeps up. Many of the districts have been exhausted, but others have been discovered, and many of the forest regions in which "gumming" is prohibited on account of the injury it does to the timber, may become available later when the timber is cut. It is probable that for many years to come gum mining will be an important industry in New Zealand.

PRELIMINARY NOTES ON SOME IGNEOUS ROCKS OF JAPAN. V[1]

S. KÔZU
Imperial Geological Survey of Japan

V. POTASH-RHYOLITE

Introduction.—The rock is of limited occurrence, forming a hill called Manzōyama, with the height of 200 meters above the sea-level and the base-area of about 1.62 square kilometers, standing near the bay of Shimoda, which is situated at the southern end of the Izu Peninsula, projecting southward from the middle of the main island of Japan, and is well known as the port first visited by Commodore Perry.

The rock occurs as a lava-flow, not widely extended, but of considerable thickness. On the southwestern foot of the hill, a distinct prismatic jointing in the lower part of the lava can be observed. Its eruption was preceded by that of the so-called plagioliparite, and was followed by an enormous outpouring of andesitic rocks after a somewhat long interval. The eruptions of these rocks seem to have happened about the middle of Tertiary time. Tuffites derived from these rocks contain sharks' teeth (mostly *Carcharodon megarodon* and *Lamina* sp.), *Lithothamnium*, and several kinds of foraminifera. The age of the formation is considered as Miocene.

Petrographical characters.—Megascopically, the rock is characterized by its color, which varies from brownish-red to light reddish-gray with a violet tinge, which distinguishes it from other rocks occurring in the region. Its texture is indistinctly porphyritic, owing to the small size of the phenocrysts, from 1 mm. to 2 mm. in length. The only phenocrysts are feldspar crystals with

[1] Published by permission of the Director of the Imperial Geological Survey of Japan.

prismatic and tabular habits, scattered in an aphanitic groundmass. There are also well-defined prismatic or irregularly outlined cavities having the crystal form of hornblende, in which the mineral material is entirely altered to a dark-brown loose substance. Their sizes are usually smaller than those of the feldspar phenocrysts. In this rock-type, phenocrysts of quartz are entirely wanting. Flow-structure is a constant feature; sometimes red flow-lines are distinctly marked in the light-colored groundmass.

Under the microscope the porphyritic character is pronounced. Fairly numerous phenocrysts of sanidine and a very small quantity of magnetite are scattered through the hyalocrystalline groundmass. Needles of apatite and minute crystals of zircon occur as accessory constituents.

Sanidine phenocrysts, which are the only important constituent mineral, occur both in tabular and in prismatic forms, with more or less rounded outline. They are simple or twinned, and in many instances, inclose clouded patches of glass and minute crystals of apatite and iron ores. The characteristic cracks, sometimes filled with reddish-brown iron oxide, are also observed. It has a low refraction and low double refraction, and exhibits a very small optic angle, which is nearly zero. In a specimen of brecciated lava, the sanidine is entirely replaced by a colorless substance which is isotropic, and has slightly higher refraction than that of Canada balsam. From these characters, it appears to be opal.

The groundmass consists essentially of potash-feldspar and devitrified glass in nearly equal proportion though their relative amounts vary somewhat in different places. The feldspar is variable both in shape and size. Some of the crystals show a distinct prismatic form, commonly twinned, but others are irregularly outlined. The glass base is more or less densely clouded with reddish-black, opaque spots or rods, their presence affecting the color of the rock. In rare instances very minute flakes of deep reddish-brown mica can be detected among them.

Chemical characters.—The analysis of the rock, from the western foot of Manzōyama, was made by K. Yokoyama in the laboratory of the Survey. The result is given as follows:

	A	B	C
SiO_2	70.75	68.13	69.06
Al_2O_3	12.44	15.75	14.41
Fe_2O_3	2.66	1.60	1.89
FeO	0.79	0.74	0.54
MgO	0.08	0.45	0.39
CaO	0.39	0.27	trace
Na_2O	0.39	0.61	0.24
K_2O	11.51	10.54	12.33
H_2O	0.84*	1.90	0.96
TiO_2	0.53	0.31	0.24
P_2O_5	0.10	trace	0.08
MnO	0.09	....	....
SO_3	....	0.07	0.28
CO_2	....	....	0.24
Total	100.57	100.37	100.51

* Loss on ignition.

A. Potash-rhyolite from Manzōyama, Izu. K. Yokoyama, analyst.

B. Quartz-porphyry from Himmelberg, Bl. Lebach, Prussia, described by Weiss and Gebe. K. Boettcher, analyst.

C. Quartz-orthoclasite from Mutterbach. Masserthal, Thueringerwald, described by H. Loretz. Hampe, analyst.

The chemical character of the rock from Manzōyama is noticeable on account of the extremely high percentage of potash, from which it is seen that the sanidine is entirely free from isomorphous mixtures of other feldspars. The quartz-porphyry from Himmelberg and quartz-orthoclasite from Mutterbach, the chemical compositions of which are given in columns B and C, are quite similar to the rock from Manzōyama.

	A	B	C
Quartz	25.2	23.2	19.9
Orthoclase	67.8	62.3	72.8
Albite	....	5.2	2.1
Anorthite	....	1.4	....
Corundum	....	2.8	0.6
Acmite	2.8	....	....
Diopside	0.7	....	....
Hypersthene	....	1.1	1.0
Ilmenite	1.1	0.6	0.5
Magnetite	0.6	1.4	1.2
Hematite	1.1	0.6	1.1
Apatite	0.3	....	....
Total	99.6	98.6	99.2

From the norms, ratios are given as below.

	A	B	C
$\frac{Sal}{Fem}$	14.09	25.41	25.11
$\frac{Q}{F}$	0.37	0.33	0.27
$\frac{K_2O'+Na_2O'}{CaO'}$	∞	24.4	∞
$\frac{K_2O'}{Na_2O'}$	∞	11.20	32.75

The magmatic name of the rock from Manzōyama is lebachose, in which division only a few rock-analyses are so far known to belong. On account of the richness in potash, the writer distinguishes the rock as potash-rhyolite.

GRAVEL AS A RESISTANT ROCK[1]

SIDNEY PAIGE
U.S. Geological Survey

In a recent[2] number of the *Journal of Geology*, Mr. John L. Rich presents the thesis that "gravel, in its relation to the agencies of denudation, is under certain geological conditions a highly resistant rock. To these agencies it will, in general, offer greater resistance than ordinary igneous or sedimentary rocks, with a few possible exceptions."[3]

The writer is in accord with this general thesis; but the specific evidence presented in arriving at this conclusion is not wholly accurate, and certain deductions affecting the physiographic history of the region should in the writer's opinion be interpreted differently.

Mr. Rich divides his paper into three parts: (1) to point out the theoretical reasons for the resistant nature of gravel deposits; (2) to show, from an actual occurrence in nature, that the gravels do behave as the theoretical considerations would lead us to expect; and (3) to sketch by way of suggestion the normal course of development of topography in a region where alluvial fans of coarse material are accumulating at the base of mountains. It is especially with No. 2 that the following has to deal.

It is shown that a plain-like lowland lies between the northern edge of the gravel deposits and the high mountains to the north. This lowland is in places 100 feet below the base of the gravel south of it, and is crossed by the mountain streams flowing southward out upon the desert deposits.

To explain this feature Mr. Rich presents three alternative hypotheses: (1) The gravels may have been removed by erosion

[1] *Jour. Geol.*, XIX, No. 6.

[2] *Op. cit.*, p. 492.

[3] Published by permission of the Director of the U.S. Geological Survey.

from the area between their present limit and the mountains; (2) There may have been faulting by which the lowland was relatively lowered; or (3) The mountains may have been worn back and the lowland developed by differential erosion since the deposition of the gravel.

Mr. Rich adopts the latter explanation and presents evidence to show that No. 1 is impossible. I wish first to indicate wherein the statements used as evidence to disprove No. 1 are inaccurate, and second to show that a combination of No. 1 and a part of No. 2 is the more plausible explanation of the observed facts.

Mr. Rich says:

> Opposed to the first of these alternatives is the fact that the gravel plateau ends abruptly along a relatively straight line. There are no outliers of gravel between this general line and the mountains. It is highly improbable that streams flowing nearly parallel and not more than a mile apart should strip all signs of the gravels from the upper four miles of their course, while in their lower course, where they flow across the gravel plateau, they should be in relatively narrow valleys with almost no tributaries and should have done little more than to cut their way through the plateau without having been able to widen their valleys to any great extent (Fig. 2).
>
> A second objection is the fact that the line of contact between the gravels and the underlying rock slopes upward toward the mountains at such an angle that it would intersect the projected line of the plateau surface at a point not far within the present limit of the gravels (see Fig. 5). In other words, the gravels thin toward the mountains at such a rate that they would wedge out within a short distance from their present limit, and the lowland is accordingly developed in the bed-rock.

On that portion of the geologic map of the Silver City quadrangle shown by Mr. Rich two important outliers have been omitted. Their position is shown in Fig. 1, *a* and *b*. Still another outlier is present at *c*, which position was just off the western edge of the first map. Nor should it be said that the gravel plateau ends abruptly along a relatively straight line, for as shown on the map the edge of the gravel plain has many of the characteristics of an erosion border. Further, it is not "highly improbable" that streams flowing nearly parallel and not more than a mile apart should strip all signs of the gravels from the upper four miles of their course, for a point which has failed to be considered here, though it is mentioned in another place (p. 500, line 3), is that *an increased*

gradient near the mountain core probably existed; first, because such an increased gradient is normal, and second, because there is in this entire region strong evidence of post-Pleistocene tilting (due to faulting) in the north.

Next, the diagram, Fig. 5[1] (used as evidence in the argument that the gravels never extended farther mountainward), is misleading. By actual outcrop on the map it may be shown that the gradient of the gravel *base*, measured from a *ridge top* to a

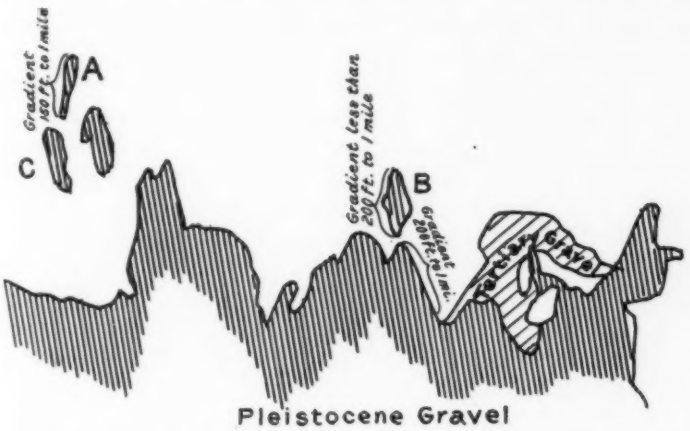


FIG. 1.—Showing irregular edge of gravel sheet and outliers north of it

valley bottom (the most favorable measurement), in places does not exceed 200 feet to the mile. The diagram shows a gradient of 1,500± feet to the mile. The long thin outlier north of Silver City has a basal gradient approximating 100 feet to the mile. The outlier on the extreme west has apparently a still lower gradient. The diagram is misleading because, with the low gradient that is shown above to exist, and with a gravel plain the top of which has an increasing gradient, the gravel might well have extended farther mountainward.

Further to cast doubt on the hypothesis that the mountain front once stood at the present position of the gravel edge and

[1] *Op. cit.*, p. 501.

that the gravels did not extend farther northward, the following facts are submitted. The lava series (composed of igneous sheets and interbedded gravel deposits at each locality of essentially the same character) is found north, northwest, northeast, southeast, and southwest of this area. A deposit of gravel belonging to this series actually underlies the Pleistocene gravel at the eastern side of the map (see Fig. 1). Besides these facts there is clear structural evidence, which need not be considered here, which leads to the inference that great lava sheets once *covered* this entire area, and that the gravel which now occupies this space at the surface is the débris derived from the denudation of the great up-faulted portions of these sheets, of which such masses as the Little Burro Mountains, Lone Mountain, and the Silver City Range are the remnants. From this it is logical to conclude that the present frayed northern edge of the gravels occupies its position, not because it represents an old scarp line, but because it represents a position of stability established by a number of factors—gradient, rainfall, favorable location with respect to drainage, etc.—all acting on a gravel sheet which originally extended farther northward. After the edge was eroded back to this position of stability, it is conceivable—in fact, is probable—that differential erosion carved out the lowland lying north of it.

To sum up: The gravels have been removed by erosion from a portion of the area between their present limit and the present position of the mountains, and the lowland has been developed *in the old floor* upon which these gravels once rested, by differential erosion.

SOME OBSERVATIONS AND EXPERIMENTS ON JOINT PLANES[1]

PEARL SHELDON

I

INTRODUCTION
- Folding
- Faulting

OBSERVATIONAL WORK
- Joint Planes
  - Fall Creek Joint Planes
  - Joints of the Entire Region
    - Strike Joints
      - Effect of the Rock Character
      - Hade of the Strike Joints
    - Dip Joints
      - Hade of the Dip Joints
    - Minor Joints
  - Influence of Joints on Topography

II

EXPERIMENTAL WORK
- Network of Cracks
- Finest Cracks

DEDUCTIONS
- Age of the Joint Planes
  - Strike Joints
  - Dip Joints
  - Evidence of the Dikes
- Cause of the Joint Planes
  - Tension Theory
  - Earthquake Theory
  - Torsion Theory
  - Shear Theory

[1] This was done as part work for a Ph.D. degree at Cornell University. Acknowledgments are due to Professors R. S. Tarr and G. D. Harris for information and criticism.

I

INTRODUCTION

In an attempt to find the age of the joint planes of the Ithaca region with reference to the low folds which occur here, observations were made on 3,046 joints. Nearly all of these readings included both strike and inclination, although in a few cases one or the other was necessarily omitted. Over six hundred readings were made in the Fall Creek gorge at localities 55 to 58 and part of 54 in Fig. 7. For this distance readings were made on every accessible joint which was strong enough to show for two or three feet and not so variable that the data would be of little value. Occasionally observations were made on more poorly developed joints which were locally characteristic.

Although later work showed that this locality was hardly typical in some respects, this study showed how the joints of a single area vary with their strike and formed a basis for later work by showing which sets of joints are constant and strong and which too variable and weak to be of value in comparing different localities. During one summer and fall about two thousand readings, including this six hundred, were made in the Ithaca region. The following winter was given to experimental work and examination of the data already taken, and during the next summer another thousand readings were made in completing the section and investigating points connected with the theory, particularly the faulting.

Only a part of even the master joints could be read in the field but those were chosen which local observation and work in neighboring areas showed to be most characteristic for each place and, because of their constancy, most valuable for comparison with other areas. The work was begun without a conviction in favor of any one of the theories for the formation of joints and most of the evidence of their age was unexpected, so that the choice of readings was influenced little by preconceived ideas.

The data had a bearing on several points besides the age of the joints. The following are some of the results obtained:

Nearly all the uniform and strong joints fall into two groups.

Those in one group strike nearly parallel to the axes of the folds and form the strike set.

Those in the other group strike approximately along the dip of the rocks and are the dip joints.

The dip joints form two distinct, similar sets and appear to vary with the pressure which caused the folding.

The strike and dip joints are usually nearly vertical and a single joint varies little in strike and inclination at any exposure. The joints belonging to each set have a range in strike of only a few degrees at any one locality.

A set of joints making a moderate angle with the strike set is locally strong but these are not of the same character as the strike and dip joints. They are more variable in strike and inclination and usually have a greater hade.

Joints striking between the major sets are common but are usually weak and very variable with little apparent system. Their hade is usually large. In some localities the highly inclined joints are strong.

The master joints were evidently formed during the earlier part of the folding which took place here during the Appalachian Revolution. They are not younger than the faults which were formed at that time, since they are displaced by the faults. The hade of the strike joints shows that they were not formed before the folding. The dip joints vary with the folds and the forces active during the folding and were apparently formed at that time.

By compressing blocks of paraffin and resin various systems of cracks were obtained. Some were like those obtained by Daubrée. The finest cracks were nearly parallel to, and at right angles to, the pressure.

The observations support the shear theory of the formation of joints by indicating that the joints here were formed while shearing stresses were active and that the joints vary with those stresses. The joint planes, however, are nearly at right angles to the fault planes and are very unlike them, so that the theory that joints are incipient faults is not supported. Some factor like shock may have determined the position of the breaking planes which are classed as joints.

FOLDING

In general the rocks of the Ithaca region dip slightly to the south so that successively older strata are exposed to the north in the lake section. In the area studied the outcrops are Hamilton shale, Tully limestone, Genesee shale, and Portage sandstone and shale. The southward dip is not uniform, however. The region is crossed by a series of low folds which have been described and mapped by E. M. Kindle.[1] They have been more briefly described by H. S. Williams,[2] and one of them by S. G. Williams.[3]

In the Watkins Glen–Catatonk quadrangles the anticlinal and synclinal axes occur a few miles apart and their directions are usually somewhat north of east. The folds die out east of the longitude of Ithaca. Three of these axes—the Enfield syncline, Watkins anticline, and Corbett Point syncline—cross the Ithaca region. They are shown in Fig. 6, copied from *Folio 169*. The dotted lines represent approximate location. North of these axes and beyond the northern boundary of the area included in *Folio 169* is a well-developed fold which is conspicuous along Cayuga Lake because it is outlined by a prominent outcrop of Tully limestone. The point where the anticlinal axis crosses the western shore is accurately shown by a hard layer in the Hamilton shales which rises a few feet above low-water level at the highest point of the fold. The highest point on the eastern side is not so well shown but the direction of this axis as drawn in the upper part of Fig. 6 is correct to one or two degrees. It is a pitching fold. S. G. Williams gives the height of the Tully limestone outcrop on the west side as 160 feet and on the east side 235 feet above lake level. This has been called the Ludlowville fold and the Shurger Point fold.

From this axis the rocks descend to the northern limit of the map but the dip is not uniform. First there is a sharp dip, then a nearly horizontal region, then another steep dip to the north, thus forming a small fold on the northern limb of the main anticline.

[1] *Jour. Geol.*, XII, No. 4 (1904), 281–89; *Folio No. 169, U.S. Geol. Surv.* (Watkins Glen–Catatonk quadrangles), pp. 13–15; field edition pp. 98–107.

[2] *Proc. Am. Assoc. Adv. Sci.*, XXXI (1882), 412.

[3] *Am. Jour. Sci.*, 3d ser., XXVI (1883), 303–5.

The axis of the small anticline probably lies just south of the mouth of Taughannock Creek and the axis of the corresponding syncline about half-way between the mouths of Taughannock and Willow creeks. This fold is present on the eastern side of the lake but its axes were not determined there.

In the Inlet Valley the Watkins anticline is similar to the fold just described. It is represented by nearly horizontal rocks on the northern limb and inclined rocks on the southern limb. Further west, at Seneca Lake, the fold is stronger, with northward dips in the northern limb. South of the Enfield syncline is a strong anticline which reverses the dip.

In the area studied, therefore, there are three anticlines and three synclines with the Shurger Point fold the most strongly developed. The other two folds are represented by changes in the inclination of the beds without reversal of dip on each limb of the larger fold.

The dips of these low folds in southern New York range from 0° to 10° and are usually small. Though weak, the folds are persistent and are nearly parallel to the high mountain folds south of the Pennsylvania line. There seems no reason to doubt Kindle's conclusion that they were formed during the Appalachian Revolution. No folds of any other date are known here, so that the structure is comparatively simple. Broad warpings like that described by M. R. Campbell[1] apparently have not affected the problem of the joint planes.

FAULTING

Kindle[2] described a few small faults of variable character in the Watkins Glen–Catatonk quadrangles. G. C. Matson[3] mentioned several cases of movement along bedding planes and minor thrust faulting. He found that the dikes which cross some of these slipping planes were displaced, the maximum displacement given being two feet.

The ordinary type of faulting in this region is nearly horizontal

[1] *Bull. Geol. Soc. Am.*, XIV (1903), 277–96.

[2] *Folio 169*, p. 15; field edition, p. 108.

[3] *Jour. Geol.*, XIII, No. 3 (1905), 264–75.

thrust faulting with small displacement. These faults are numerous, occurring by the score in the shale beds, especially in the Hamilton shales. Often several may be seen in the height of a single cliff. Since these faults do not, as a rule, cross bedding planes the amount of movement is indicated only by the displacement of the joints, which are nearly at right angles to the faults. Whether or not this shows the total movement depends upon the

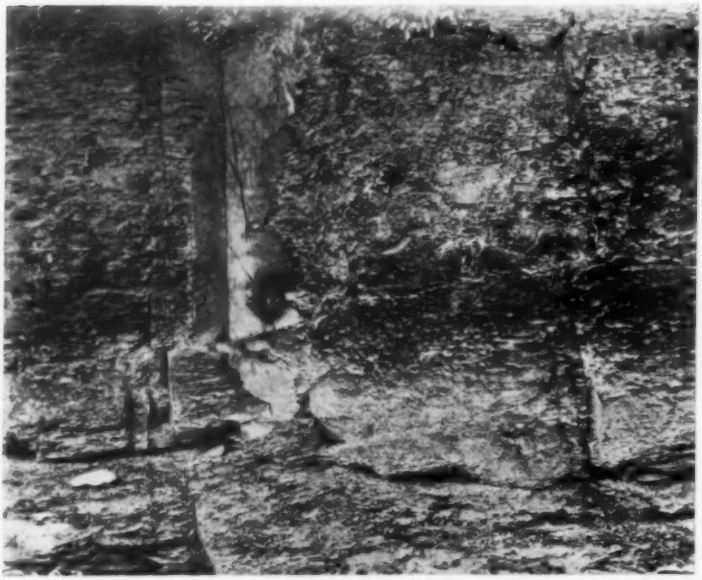


FIG. 1.—Two faults in the Hamilton shales. The eroded horizontal line is the lower fault. The upper fault descends to the left.

relative ages of the joints and faults. Perhaps some faulting took place before the joints were formed. The displacement is usually between a fraction of an inch and seven or eight inches. Four to six inches is common and a single outcrop of a fault will sometimes show progressive variation through almost the entire range of displacement found in these faults. In other places the displacement is nearly constant for rods.

One of the best faults seen in the Ithaca region is in the Hamilton shales where Salmon Creek falls over the Tully limestone back of Ludlowville. It passes around the base of the fall, just above the level of the pool, disappears beneath débris, then reappears and

FIG. 2.—Right-hand continuation of the faults shown in Fig. 1. The head of the hammer shows the movement along the upper fault.

continues downstream just above the creek bed for many rods. It is made conspicuous by stream erosion along the fault line.

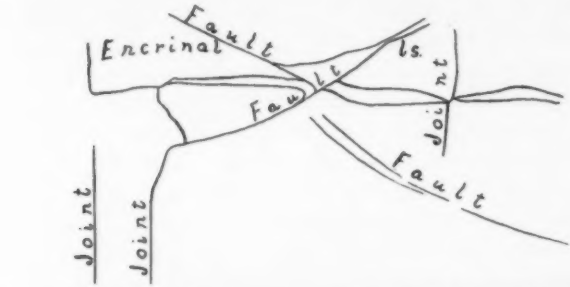
To casual observation these faults look like weak, slightly weathered bedding lines. Inspection shows the displacement of the joints across them and where they are exposed to stream or

wave cutting they appear as considerably eroded lines, sometimes worn into tiny caves. Figs. 1 and 2 show two of these faults in the cliff beside the bridge where the highway enters Ludlowville from the south. The photographs are of adjacent portions of the cliff. The lower, nearly horizontal, fault is eroded by the creek which is cutting the cliff. The upper fault, which has an unusually steep angle, has a fresh exposure and is therefore inconspicuous. The displacement along the upper line is shown by the head of the hammer. The movement has been such as to thrust the central wedge-shaped mass to the left and into the cliff between the upper and lower parts of the rock.

The exact direction of movement in the horizontal faults of the Ithaca region was not determined. Something might be learned from the relative amount of displacement of the different sets of joints but this method might be subject to error because of difference in the time of formation of the different sets. In the cases observed there was not a conspicuous difference in the displacements of the different sets, indicating that the direction of thrust made a fair angle with each set there present unless much of the movement took place between the times of formation of the different sets.

The comparative behavior of the faults in soft and hard rocks is interesting. In the Hamilton shales is a hard encrinal layer a foot or two in thickness. This is shown in Fig. 3. It did not yield to pressure without breaking so readily as the adjacent shales and the exposures of this layer along the lake show faults every few feet. They soon die out after entering the shale. Fig. 3 is a photograph of two faults at locality 14, Fig. 7. The slipping surfaces of the faults in this layer are much slickensided. The vertical displacement along these faults is from a fraction of an inch to three inches.

At locality 14, Fig. 7, where the encrinal layer rises above water level, the strike of eight faults was found to vary from N. 70° W. to due W. with an average of N. 76° W. At locality 39 in the same layer eight faults varied from N. 65° W. to S. 89° W., with an average of N. 72° W. The strike of the majority was from 20–25° north of west. At locality 9 where the encrinal layer passes beneath the lake level two readings were N. 86° W., two N. 84° W.,



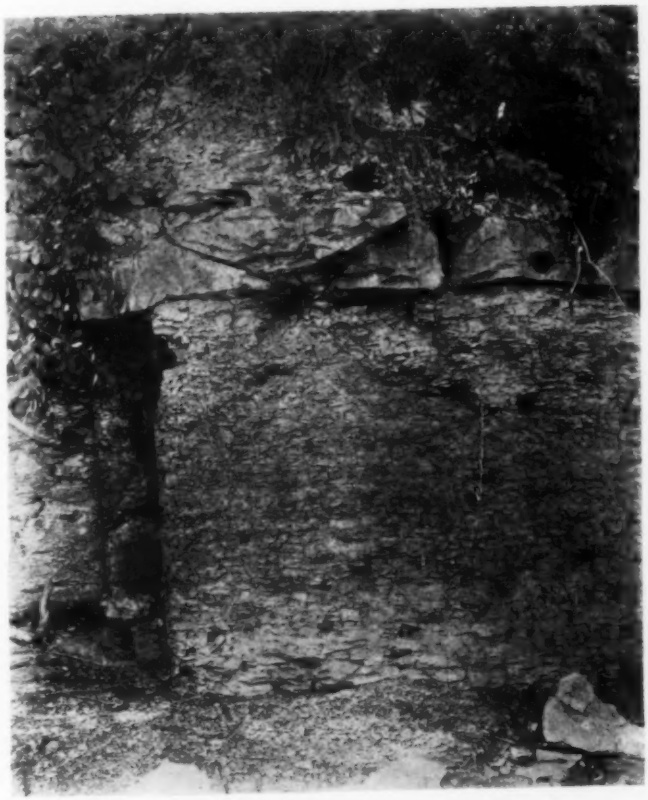


FIG. 3.—Symmetrical faults in the encrinal limestone

and one N. 80° W. These were the best seen for measurements, since one face of the faults had usually fallen away and the direction of movement could be read directly from the strong, even striations on the slickensided surfaces. Many other faults in this layer were seen but were inaccessible for measurement. The inclination of these faults is sometimes south and sometimes north and the angles are nearly the same in the two cases, making the faults symmetrical about a nearly horizontal plane. In the readings made the hade varied from 45° to 75°, but most were near the average, which was 62°. These faults usually continue for a few feet in the adjacent shale, but instead of continuing with the same hade they flatten out and become nearly horizontal as in the shales where no hard layer is present.

Since the faults of this region are usually nearly horizontal it might be expected that where well-developed bedding planes are present the slipping would take place along these. This is not true in the case of the encrinal layer. The unusually steep angle of the faults there seems to be due to the hardness of the rock, which has more influence on the location of the slipping planes than the presence of planes of weakness along the stratification. Some of the best of the horizontal faults were in nearly homogeneous shales, not along bedding planes. Evidently the bedding planes do not control the angle of the faults.

It is probable that the strike of the faults in the shales is about the same as that of the small faults in the hard layer which could be measured. It is noticeable that the strike varies from the direction of the axis of the fold by a rather large angle and that this angle increases eastward with the rise of the pitching fold. The faults were probably formed at the same time as the folds, that is, during the Appalachian Revolution, since no other disturbance of sufficient strength to produce these uniform faults is known here. The faults show that the direction of the local resultant force varied considerably from the general direction of the active force which produced the folds if the axes of the folds are at right angles to the latter. The explanation seems to lie in the pitch of the folds. Localities 9, 14, and 39 are in an anticline which rises rapidly to the east. The direction of movement points in toward

the center of a domed anticline looking from the south whence the active force came. Apparently the strike of the faults is about parallel to the strike of the rocks on the southern limb. If the pitching of a fold is due not to a variation in the active force causing folding but to a variation in the rigidity of the rocks, the molecular return forces in the soft rock near the center of the dome would not be so great as in the harder rock near the saddles and movement toward the dome might be expected. The exact analysis of the faulting is a problem in shearing closely connected with the shear theory of jointing.

OBSERVATIONAL WORK

JOINT PLANES

In measuring the joints a compass with a four-inch needle and open sights was used. The deflection of the needle from true north was taken roughly as seven degrees west. No attempt was made to read to less than a degree. The accuracy of the readings depended upon the character and exposure of each joint. The observations on most of the master joints were accurate to one or two degrees, but for the variable minor joints of large hade the error might be from five to ten degrees. The hade was measured with a six-inch protractor to which a lead was attached by a thread. Wherever possible the measurements of hade were made from such a distance that the edge of the protractor covered nearly the whole height of the exposure in order to obtain a good average. The readings were usually made to one degree. The master joint readings were mostly correct to one degree but for minor joints the error might be several degrees.

FALL CREEK JOINT PLANES

In the upper part of the Fall Creek gorge all accessible joint planes except the smallest and most variable were measured. Fig. 4 shows the orientation of these joints. The readings are tabulated by the method used by Professor Tarr for the joints of Cape Ann.[1] The strikes are divided into groups of three degrees,

[1] *Ninth Ann. Rep. U.S. Geol. Surv.*, 1887–88, pp. 583–88.

each beginning at the west so that the outer rays are N. 90° W.–N. 88° W. and N. 87° E.–N. 89° E. The figures in the margin give the number of readings to each group of compass directions. Fig. 4 shows that in direction the joints fall conspicuously into groups or sets. One set whose strike is usually between N. 70° E. and N. 80° E. is strong and nearly constant in direction and hade. Although the extreme readings of strike in this set vary by twelve or thirteen degrees the majority fall within four or five degrees. The hade is also nearly uniform. At locality 57, one hundred forty-six joints belonging to this set were measured. The total range of

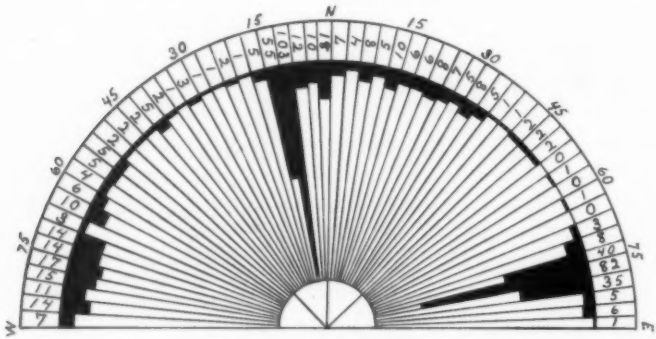


FIG. 4.—Tabulation of the strike of the Fall Creek joint planes

hade was from $6\frac{1}{2}°$ S. to 9° N., but only two of the entire number showed an inclination to the south and most of those to the north fell within a range of a very few degrees. This set is well developed at Forest Home, locality 57, but not elsewhere in Fall Creek. Localities 55, 56, and 58 afford only a few readings and those not very good. This set is best developed in the shale beds, and the variation with the character of the rock may account for its presence at Forest Home, where shale beds are common, and its poor development in the more sandy layers above and below. The joints of this set strike nearly parallel to the strike of the rocks and form the set known as the strike joints.

Nearly at right angles is another set most of whose readings are between N. 10° W. and N. 15° W. They represent the set called

dip joints. These joints are strong, especially in the sandy layers, where they are conspicuous. As in the strike set, the hade is small and uniform. In a single small area the strike of the dip joints varies less, perhaps, than the strike of the strike set, but from place to place the variation is greater. Farther down the creek the average angle with the north is smaller. In upper Fall Creek there is little evidence of a second dip set, common elsewhere, which makes a small angle with the set just described. In Fig. 7, locality 55, is shown the average of some poor joints which may belong to this second dip set.

Besides these, certain joints with much more variable strike between 60° W. and W. might be considered as a set. In some places where the strike set is weak this set has a development which, though less regular than in the strike and dip sets, is quite strong and distinguishes the set from the mass of small joints. The hades are usually larger and less uniform than in the strike and dip sets. These joints are often curved and the smaller ones, especially at Forest Home, often show a sigmoid horizontal outcrop with the hade varying from one side to the other with the curve.

The rest of the joints of this area may be classed as weak and variable. For thirty degrees east of north the variable joints are more common and may be due to the tendency for a major set to form in that direction, but in the upper Fall Creek gorge they do not form a recognizable set. Variable joints a foot or two in length strike toward every point of the compass. Their hade is usually high, from 30° to 60°, and as a rule both the strike and hade vary over even the small extent of these joints. Enough readings were made on these to indicate their general character. They are common, but unimportant in comparing the variation of the joints with the folds.

The study in Fall Creek showed that joints of all directions are present but that those of different directions vary greatly in character. There are two sets in which the individual joints are strong and, what is more important, each joint is nearly the same throughout its extent and the joints of each set are nearly constant for one locality. It was apparent that these could be used in comparing different areas but readings on the variable joints would be of little

value. With these two sets belongs the second dip set found in other localities.

JOINTS OF THE ENTIRE REGION

Fig. 5 is a tabulation of all the strikes read throughout the Ithaca district, over three thousand in number. They are arranged in groups of five degrees each. It must be remembered that, with the exception of the six hundred also shown in Fig. 4, these joints were selected, so that the figure does not give a true record of the numerical occurrence of the various strikes but rather of the relative importance of the joints in each direction.

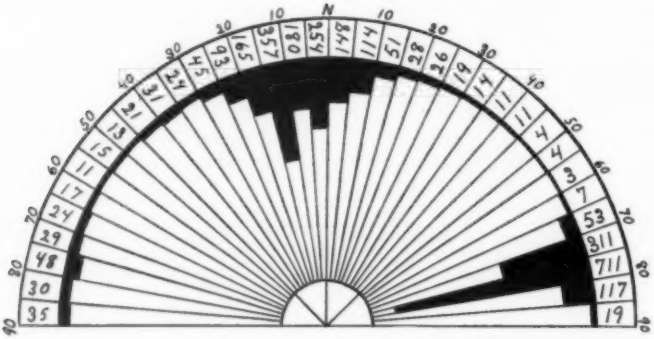


FIG. 5.—Tabulation of the strikes of the joint planes of the Ithaca region

STRIKE JOINTS.—In the Ithaca region the strike set is the most important. Fig. 5 shows that for the entire area studied far the greater part of all the joints which may be considered as belonging to this set do not vary more than ten degrees in strike. As the figure shows, there is almost no tendency for the strike set to grade into the minor joints at each side. This set is even more sharply defined and easily recognizable in the field.

The area studied was divided into squares of about a quarter of a mile on an edge. For Fig. 6 the readings of the strike joints in each small area were averaged together and the average is given beside a line drawn in the average direction. The center of the line is in about the center of the area considered and the width of the line is proportional to the number of readings included in the

average. A width equal to half a mile on the scale represents one hundred readings. Where the joints in any area vary in direction more than is usual in this set the average direction is given in light figures. Where the variation is less than usual the figures are heavy. It will be seen from Fig. 6 that the average directions are nearly parallel to the axes of the folds. It is noticeable that for the four localities along Salmon Creek, where this set is well developed, the average directions do not vary half a degree, though the individual readings vary by several degrees. There is a certain actual variation from place to place not due to the thoroughness with which observations were made. For example, just south of Crowbar Point and also on the opposite side of the lake the average angle is unusually low even though the number of readings is sufficient to give a reliable average. The cause of such deviations probably lies in the local variations of the forces producing the folds and joints. Near the Shurger Point anticline, which rises to the east so that the strike of the rocks is not parallel to the axis, the average strike of the joints does not turn so that it is parallel to the strike of the rocks, but in the opposite direction so that the strike of those south of the axis points slightly in toward the center of the domed anticline. Just how the strike joints vary with the pitching of folds cannot be determined from this one region. Further study of well-developed strike joints near pitching folds is necessary to warrant conclusions. In the southern part of the area studied the strike set is too poor to give reliable evidence.

Effect of the rock character.—The variation between the two averages near the mouth of Taughannock Creek is due to the character of the rock. The upper readings were in the Tully limestone, the lower in the Hamilton shales directly beneath the limestone. Few readings were made in the Tully elsewhere but a similar variation from the strike in the shales was noticed in other places. The hardness of the rock has a decided effect on the strike joints. They seem best developed in homogeneous shales, especially the Hamilton beds. This is partly indicated by the abundance of readings on this set in the northern part of the map. South of the lake the rocks are hard Portage sandstones and shales, and the meagerness of readings, though partly due to poorer rock out-

crops, fairly indicates the lack of development of this set. At Enfield Falls this set is fairly good and at Forest Home on Fall Creek it is well developed. The same effects may be seen in one locality. At Forest Home there are alternate shale and sandy layers. The strike joints are better developed in the shales and the dip joints in the sandy beds. If the contact between the two kinds of rock is sharp both sets often cease at the contact, the strike joints passing only through the shale and the dip joints only through the sandstone. In other places a change in hardness was found to affect the strike joints, sometimes causing them to cease abruptly.

Often where the strike set is poorly developed in the harder Portage beds the set striking a little north of west is unusually well developed, almost replacing the genuine strike set. This set appears mainly in the harder rocks. It is apparently not of the same origin as the strike set, since it is always less uniform even where stronger. This is well illustrated in Lick Brook where the conspicuous joints are the two dip sets and the westerly set. The westerly joints have a large hade and are not uniform but the strike joints, though few, are nearly vertical and more regular.

Hade of the strike joints.—In comparing the joint planes and folds more can be learned from the hade than from the strike. In Fig. 6 the second part of the statement of each average indicates the average hade. If the number is heavy it means that the angle of hade varied only a few degrees; if light, that the angle varied over ten or fifteen or more degrees. A light letter indicates that part of the readings were to the north and part to the south. A heavy letter means that nearly all were in one direction or the other, and the heaviest lettering that none were in the opposite direction. The average number is taken from the algebraic sum of the north and south readings.

In the region of the Enfield syncline most of the readings were slightly to the south, though only those at Enfield Falls were very reliable. At the southern border of the area the few readings taken were so variable that they averaged 0°. Between the axes of the Watkins anticline and Corbett Point syncline the strike joints are poor for reading of hade in most places. In many cases the outcrops do not permit a reliable reading and in most places the hade

is variable. Fig. 6 shows that many of the variable areas give averages to the south but the areas of greater constancy usually show averages to the north. The only really good area of strike joints in this district is at Forest Home. There, out of 146 readings only two were to the south. It is fair to assume that on the northern limb of the Watkins anticline the tendency is to the north.

From the axis of the Corbett Point syncline northward for about three miles the tendency is to the south. On the eastern side of the lake the readings are nearly all to the south from a point somewhat south of the axis of the syncline to a point about three-fourths of a mile north of Esty Glen (locality 43). On the western side the readings are more variable but the areas of more numerous and constant readings are strongly to the south. North of this is a region of variable joints on both sides of the lake. On the eastern side the three zeros represent one average of exactly zero and two averages of small fractions to the north. Just south of Shurger Point the readings are mostly to the south, north of Shurger Point they are variable with an average of about half a degree to the north. Just south of the anticlinal axis they are again nearly all to the south. Much the same thing occurs on the western side but there the northerly tendency predominates. Judging from the other folds a small change in the dip of the rocks, not sufficient to reverse the direction of dip or even to make the beds horizontal, might explain the behavior of the joints. Such a flexure might be local or a continuation of a fold dying out here. On the eastern side this turns the hades slightly to the north for a short distance but the general southerly tendency predominates. On the western side this flexure acts as if it merged with the main axis, either reversing the readings or making them variable from a point south of Crowbar Point to the main axis. Continued folding after the formation of the joints would also explain this irregularity. South of the axis of the fold the average hades to the north are so small that if the plane of the bedding instead of the horizontal were used as a datum plane the averages in most cases would be to the south.

North of the axis of the Shurger Point fold the hades are unusually uniform and satisfactory. Along the shore north of Salmon Creek the cliffs are talus covered and falling where acces-

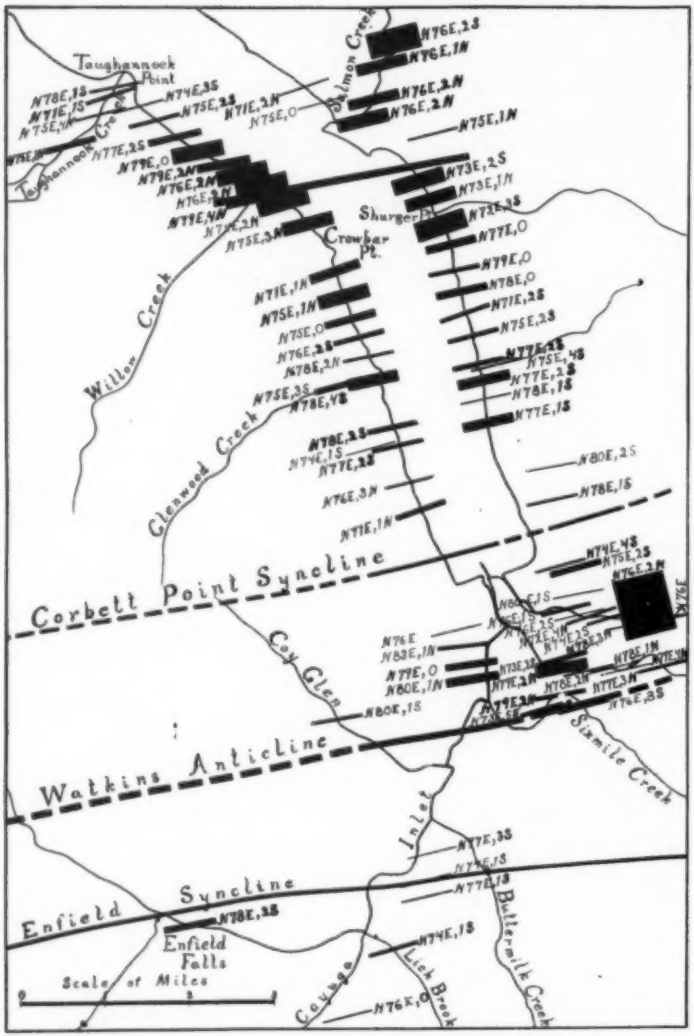


FIG. 6.—The axes of the folds and the average strikes of the strike joints

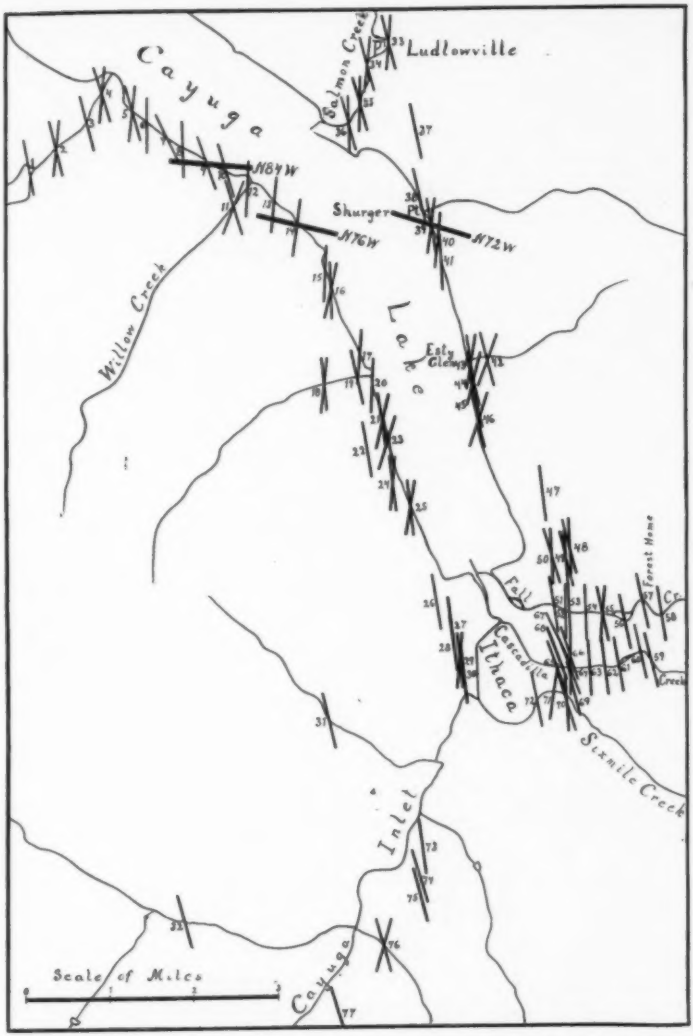


FIG. 7.—The strike of the faults and the average strikes of the dip joints

sible, so that the few readings made there are unreliable, but they are mostly to the north. On the eastern side of the lake the first area north of the axis and the first three in Salmon Creek show no readings whatever to the south, though the most northerly of the three shows a few zeros. Out of 61 readings at the fourth locality only one is to the north. There are a few zeros and the rest are to the south. Evidently there is a sharp reversal of the hade between the third and fourth localities. Because of a break in the rock wall at this point the transition only appears in the few variable readings at the adjacent localities.

On the western side of the lake no readings to the south appear for three-fourths of a mile north of Willow Creek. Then after an interval of transitional variable hades the readings are all to the south as far as Taughannock Point. The observations from the Taughannock gorge are not reliable for hade. Those in the lower part of the gorge are mostly from outcrops of slight vertical exposure, and near the falls (locality 2) the large amount of faulting and recent slipping make the readings untrustworthy. The hades just north of Willow Creek are small and are unusually uniform numerically. Between Willow and Taughannock creeks the reversal of hade takes place about where the dip of the beds changes from a strong dip to the north to horizontal. The steeper dip is resumed near Taughannock Point. On the eastern side of the lake a hard layer of rock was found to be nearly horizontal at the place where the hade of the joints is to the south but the variation in dip of the rocks was not traced. Evidently the sharp change of hade at the edge of Ludlowville is in a syncline.

Thus it appears that, in general, the inclination of the strike joints is in the same direction as the dip of the rocks or rather is such that, if the planes of the joints were produced, they would meet above anticlines and below synclines. The better developed the joints and more uniform the hade the more nearly true this is. Even folds not strong enough to reverse the direction of dip reverse the joints.

Dip Joints.—Next in importance are the dip joints. In the upper Fall Creek gorge there is a strong set of joints nearly at right angles to the strike set. In most of the other localities it was found

EXPLANATION OF FIG. 7

Locality	No. of Readings	Average Strike	Constancy	Average Hade	Constancy
1	4	N. 10° W.	High	2° W.	High
2	20	N. 14 W.	Low	5 E.	Low
	7	N. 5 E.	Fair	7 E.	Fair
3	4	N. 15 W.	Fair	1 E.	High
4	9	N. 17 W.	Fair	1 W.	High
	7	N. 5 E.	Fair	0	High
5	1	N. 16 W.	....	3 E.	....
	1	N. 6 E.	....	0	....
6	2	N. 1 W.	Fair	1 W.	Fair
7	9	N. 26 W.	Low	3 E.	Low
8	3	N. 2 W.	High	3 W.	Fair
9	7	N. 19 W.	Fair	0	High
10	10	N. 17 W.	Fair	0	High
11	6	N. 17 W.	Fair	3 E.	Fair
	7	N. 21 E.	High	0	High
12	4	N. 2 E.	High	1 W.	Fair
13	32	N. 5 E.	Fair	1 W.	Fair
14	25	N. 7 E.	Fair	2 W.	High
15	4	N. 2 E.	High	1 W.	High
16	12	N. 2 W.	Fair	2 E.	Low
	2	N. 12 E.	Fair	0	High
17	3	N. 3 E.	High	2 W.	Fair
18	20	N. 6 W.	Fair	0	Fair
	7	N. 5 E.	High	0	Fair
19	24	N. 13 W.	High	0	High
20	1	N. 1 E.	....	....	....
21	4	N. 9 W.	Fair	0	Fair
	5	N. 12 E.	Fair	1 W.	Fair
22	16	N. 10 W.	Low	6 E.	Low
23	10	N. 12 W.	Low	0	Low
	3	N. 16 E.	Fair	2 W.	High
24	4	N. 8 W.	Fair	0	Fair
	7	N. 3 E.	Fair	2 W.	Low
25	4	N. 7 W.	High	1 E.	High
	6	N. 8 E.	Low	2 E.	High
26	15	N. 10 W.	Fair	2 E.	Fair
27	21	N. 9 W.	Fair	3 E.	High
28	2	N. 10 W.	Low	7 E.	Low
29	8	N. 7 W.	Fair	11 E.	Low
	16	N. 3 E.	Fair	3 E.	Low
30	13	N. 7 W.	Fair	3 E.	Fair
31	3	N. 14 W.	Fair	1 E.	Low
32	8	N. 16 W.	High	1 W.	High
33	9	N. 14 W.	High	0	Fair
	78	N. 4 E.	Fair	2 E.	Low
34	5	N. 13 W.	Fair	1 E.	Fair
	19	N. 8 E.	Fair	4 E.	Fair
35	14	N. 15 W.	High	0	High
	22	N. 1 E.	Low	9 E.	Fair
36	2	N. 15 W.	Fair	9 E.	Low
	29	N. 1 W.	High	12 E.	High
37	6	N. 14 W.	Fair	1 E.	High
38	5	N. 15 W.	High	2 E.	High

EXPLANATION OF FIG. 7—*Continued*

Locality	No. of Readings	Average Strike	Constancy	Average Hade	Constancy
39	2	N. 9 W.	Fair	15 W.	Fair
	14	N. 7 E.	Fair	5 W.	Fair
40	6	N. 5 E.	Low	1 W.	Fair
41	6	N. 3 W.	High	1 W.	High
42	1	N. 14 W.	....	1 W.	....
	2	N. 19 E.	Fair	1 W.	High
43	6	N. 9 W.	Fair	0	Fair
	3	N. 8 E.	Fair	1 W.	Low
44	3	N. 14 W.	Fair	2 W.	High
	5	N. 13 E.	Fair	0	Fair
45	2	N. 15 W.	High	1 W.	High
46	22	N. 14 W.	High	0	High
	1	N. 17 E.	....	0	....
47	7	N. 8 W.	Low	0	Fair
48	1	N. 15 W.	....	4 E.	....
	5	N. 5 W.	Fair	3 W.	Fair
49	12	N. 14 W.	High	1 W.	Low
	8	N. 5 W.	Fair	3 W.	Low
50	1	N. 17 W.	....	1 E.	....
	3	N. 3 W.	Low	2 W.	Fair
51	17	N. 10 W.	Fair	1 W.	Fair
52	11	N. 3 W.	High	2 W.	High
53	9	N. 1 W.	Low	2 W.	Fair
54	91	N. 2 W.	Fair	1 W.	High
55	43	N. 12 W.	Fair	1 E.	Fair
	17	N. 4 E.	Low	0	High
56	5	N. 12 W.	High	0	Fair
57	109	N. 12 W.	High	0	High
58	16	N. 9 W.	Fair	1 E.	High
59	9	N. 14 W.	High	0	Fair
60	29	N. 13 W.	High	0	Fair
61	13	N. 11 W.	High	1 E.	High
62	25	N. 7 W.	Low	3 W.	Low
63	44	N. 5 W.	High	2 W.	Fair
64	15	N. 22 W.	Fair	1 E.	Low
	2	N. 2 W.	Fair	2 W.	Fair
65	51	N. 22 W.	Fair	0	Low
66	4	N. 19 W.	High	4 W.	Fair
67	19	N. 26 W.	Fair	9 W.	Fair
68	57	N. 22 W.	Fair	6 W.	Low
69	2	N. 15 W.	High	3 E.	High
70	22	N. 18 W.	Fair	12 E.	Fair
	9	N. 5 W.	High	0	Fair
71	1	N. 8 E.	....	2 W.	....
72	23	N. 12 W.	Low	14 E.	Fair
73	11	N. 9 W.	Low	2 E.	High
74	2	N. 18 W.	Fair	1 E.	High
75	2	N. 16 W.	High	2 E.	High
76	9	N. 15 W.	High	0	Low
	3	N. 15 E.	Low	9 E.	Low
77	1	N. 18 W.	....	2 W.	....

that the dip joints do not belong to a single set. They fall into two groups, with sometimes one and sometimes the other more prominent. Practically all the strong regular joints of small hade which do not belong to the strike set lie in the general direction of the dip of the rocks, but a curve drawn between the compass directions and the number of joints striking in each direction for a locality will usually show a tendency toward two maxima. That is, the dip joints form two groups with the average of one group nearly perpendicular to the axes of the folds, somewhat west of north, and the average of the other set farther east. There may be readings continuously between the two averages, or there may be a gap with no readings in the middle. There is a decided bunching of strikes toward the extremes rather than a larger number of readings near the average value of all the dip joints.

The strike joints show no such tendency. With them a curve between strikes and number of readings has a decided maximum near the median value with the number of readings decreasing rapidly toward the extremes. In one or two places strike joints were seen crossing each other, that is, fairly strong joints with directions near the extreme range for the strike set would occur at the same place and consequently intersect, but this is rare and the strike joints clearly form a single set. The dip joints often cross each other. In many areas only one dip set occurs, as is shown in Fig. 7. In such places it is usually found that the average of all the dip joints is about the same as one of the averages obtained by dividing the readings where both sets occur, thus justifying the division in the latter case. In better cases both dip sets occur together strongly and nearly equally developed, the two sets making so large an angle with so few intermediate joints that one would not consider averaging them together as a single set.

Around the city of Ithaca the more westerly of the dip sets is dominant. Northward the more easterly set is often the stronger. At Lick Brook the two sets are about equal and do not intergrade. With the set north of west they cut the rocks into conspicuous triangles instead of the more common parallelograms where only one dip set is strong. Southward from Esty Glen the dip sets are about equal, the angle between them is comparatively large, and each

set has only a fair range of strike so that the two are entirely distinct. The line of the cliff lies between the two sets and the cliff face is in many parts composed of projecting and re-entrant angles formed by the joint faces of large area meeting in obtuse angles. The small number of readings made in that locality is due to the fact that these joints are mostly at inaccessible heights in the cliff. The directions are rather constant, however, so that the readings made are representative of all.

The angle between the dip sets varies. Some of the averages in Fig. 7, which strike nearly north, come from observations too few in number to justify division into two sets. The resulting median value does not correctly represent either set if both are present. In other places, such as lower Fall Creek, there is a well-developed set whose average is nearly north, so that the angle between the two sets is only a few degrees. The upper locality at Willow Creek shows an unusually wide angle between the set. Those readings were made in the Tully limestone, and in the dip joints as in the strike joints the hardness of the rock seems to affect the direction. Unlike the strike set, the dip joints are better developed in the sandstones than in the shales. This appears where such layers alternate and also in the general distribution of the dip sets. In some of the softer shales along the lake they are rare and they are seldom so well developed there as the strike set. In the hard Portage rocks from the end of the lake southward the dip sets are far stronger than the strike. The conspicuous joints seen in the gorges in the city of Ithaca are dip joints.

The direction of the dip joints and the angle between the two sets seems to depend on the general force which caused the folding and the angle which the variable local resultant force made with it. The two sets seem to be arranged on each side of a line which is a compromise between the two. The range of the dip joints is from a line nearly perpendicular to the axes of the folds around to the east toward the perpendicular to the strike of the faults. The small angle between the sets near the city is probably related to the lack of strong folding there. In Fig. 5 the dip sets of the different areas overlap, obscuring their double nature.

Hade of the dip joints.—The hade of the dip joints is in general

larger and less uniform than in the strike joints. In some places in the Portage rocks where the dip joints are strong and occur at regular intervals, forming joint-faced buttresses along the gorge walls, the angle is quite uniform and nearly vertical. These evenly spaced joints occur in Fall Creek, Glenwood Creek, and in the Portage beds in the Taughannock gorge.

A detailed study of the pitch of the folds is necessary before the meaning of the hade of the dip joints will be clear. In general the hade of the joints and pitch of the rocks seem to be in the same direction, though some local measurements were opposite. The joints as a rule are not perpendicular to the bedding planes.

Some of the larger angles of hade are associated with faulting. This is true along University Avenue in Ithaca (localities 67 and 68). It is more conspicuous at Taughannock Falls where joints with a vertical exposure of two hundred feet or more are nearly vertical at the top of the gorge wall and bend to an unusually large angle with the vertical near the base where several nearly horizontal faults are present. This is probably due to drag along the faults.

MINOR JOINTS.—Besides these fairly constant sets there are minor joints striking in every direction, but they are as a rule easily distinguished from the major sets by the fact that few of them are to be compared with the major joints in strength and especially by their irregularity and usually large hade. Near the Shurger Point anticline is a set of minor joints which are comparable with the major sets in strength. These joints vary widely in direction, but ordinarily make a fair angle with the strike and dip sets and always have a large inclination, from 30° to 60°. The strike is both N.E. and N.W. and the hade may be to either side in the joints of either direction. High-angled joints similar to these were seen in other parts of the area studied but usually not so well developed. In Salmon Creek highly inclined joints of about this strength are frequent but their direction is nearly the same as that of the regular strike set. In fact, some of them seem to be continuous with strike joints which are nearly vertical for part of their height, then suddenly bend to a high angle and probably change their direction somewhat also. Measurements on these

joints are only approximate because the exposures are usually poor. The rock walls quickly fall where these large diagonal planes for slipping are present. These highly inclined joints are not uniform in direction and a single joint is usually a curved instead of a plane face. They seem to be associated with the stronger folding.

Among the smaller joints of interest are certain offshoots from the dip joints. In an area where nearly all the dip joints belong to

Photograph by G. D. Harris

FIG. 8.—Jointing on the east shore of Cayuga Lake. The joints are not at right angles to the stratification but are inclined in the same direction as the beds.

one set but where there is an occasional example of the other set, or where the dip sets vary from their usual direction, the less usual joints sometimes have small cracks running off diagonally for a few inches in the more common direction of the dip joints.

Of the joints with no apparent uniformity perhaps the most interesting are the smallest. Some of the rocks, especially the Hamilton shales, are broken by a mass of tiny, smooth, curved faces of only a few inches in area. These are the faces along which the shale parts when it crumbles. They have no apparent system.

Joint planes are present in all sizes from an inch to two or three hundred feet in length and height but there is not an even gradation from one to the other extreme. The joints are divided into groups and each group shows distinct characteristics.

The strike and dip relation of the master joints of this region has been generally observed and readings have been made on the directions of the joints, chiefly by C. G. Brown whose data were used by Professor Hobbs.[1]

INFLUENCE OF JOINTS ON TOPOGRAPHY

The joint planes of this region have a marked influence on the form of gorges, cliffs, and waterfalls. The joints in the cliff along Cayuga Lake were made famous by the illustrations of Hall and Dana. Fig. 8 is a photograph of some of these joints at locality 46, Fig. 7. Their effects on gorges and waterfalls have been illustrated and described many times.[2] The rapidity of erosion seems greater where the strongest joints are transverse to the general stream direction rather than parallel to it. In the latter case small streams often follow a very narrow channel between two parallel joint faces. Where the transverse joints are strong and there are one or more sets nearly parallel to the stream, there are often broad chambers in the gorge with the walls formed by the larger joint faces and the stream entering and leaving by narrower openings. These may be seen in upper Lick Brook and in other gorges in the hard Portage rocks. The similarity between some of the larger features of drainage and the directions of the joint planes seems to be due to the fact that the streams were once consequent upon the same uplift with which the joint planes are associated.

[1] W. H. Hobbs, *Jour. Geol.*, XIII, No. 4 (1905), 363–74.

[2] R. S. Tarr, *Bull. Amer. Geog. Soc.*, XXXVII (1905), 193–212; *Pop. Sci. Mo.*, LXVIII (1906), 394–96; *U.S. Geol. Surv., Folio 169*, p. 3; field edition, pp. 24–25; *New Physical Geography; Physical Geography of New York State;* W. H. Hobbs, *Jour. Geol.*, XIII, No. 4 (1905), 363–74.

[*To be continued*]

Petrological Abstracts and Reviews

Edited by ALBERT JOHANNSEN

Craig, Wright, Bailey, Clough, and Flett. *The Geology of Colonsay and Oronsay, with part of the Ross of Mull.* Mem. Geol. Survey Scotland, No. 35. Edinburgh, 1911. Pp. viii +109; plates VI; figs. 21; map 1.

Colonsay and Oronsay are two small islands of the Inner Hebrides, lying between Islay and Mull, and are formed chiefly of schistose, metamorphic rocks of sedimentary origin and probably of Lower Torridonian age. They include limestones, phyllites, mudstones, banded flags, sandstones, feldspathic and epidotic grits, and conglomerates, and have a thickness estimated to be at least 5,000 feet. The rocks are much folded and show two series of cleavages, the earlier of which is slaty cleavage and is separated from the later "strain-slip" by a period of igneous activity, during which time there were intruded several small masses of syenite and diorite and numerous lamprophyric dikes. Subsequently a series of vogesites were intruded. No sediments are found intermediate between the Lower Torridonian and those of the Glacial period, the long interval being represented only by the igneous intrusions.

The igneous rocks consist of quartz-hornblende syenite, kentallenite, and augite diorite. There are two phases of the syenite; a marginal phase which is very basic and full of included bowlders, and an interior acid phase which is bowlder free. The marginal phase is a dark rock consisting of short, stout crystals of hornblende and a little biotite in a scanty matrix of feldspar (perthitic orthoclase, with albite in some places) usually micrographically intergrown with quartz. A peculiar feature of this border facies is the fact that it is crowded with bowlders of quartz and quartzite in all stages of assimilation, the unaltered portions being surrounded by halos of feldspathic material, usually potash feldspar and quartz with a little albite, formed by the combination of the dissolved silica with the basic magma. The "feldspathic ghosts" often retain the original shape of the bowlders and indicate the tranquillity of the process of replacement and the viscosity of the magma, the later being indicated also by the uniform distribution of the lighter quartz bowlders in the heavier magma. The authors say the rock can

best be described as hornblendite, passing into hornblende picrite in places, though differing from the normal types, which carry basic plagioclase, in that in these rocks the general feldspar is perthitic orthoclase with some albite. The rocks are intermediate between the syenites with which they are associated and the kentallenites. The influence which the included quartz bowlders have had upon the magma is shown in the local concentration of the alkalies around them. In the magma, which is predominantly hornblendic, the quartz bowlders are replaced by alkali feldspars and quartz. Calcium feldspars, such as one would expect in a calcic magma, are entirely absent.

The central acid phase of the intruded mass is quartz syenite, consisting of hornblende and less biotite in a matrix of feldspars, chiefly orthoclase with some albite, and quartz.

The kentallenite occurs in a mass about fifty acres in extent at Balnahard, and closely resembles the type rock from Kentallen Quarry. A porphyritic phase of this rock is also found.

Augite diorite, in the sense used by Hill and Kynaston, forms the largest outcrop of igneous rocks on the island. It is a black-and-white rock with about equal amounts of femag and feldspathic constituents. Under the microscope the rock shows a porphyritic texture with biotite, pale-green augite, some hornblende, and some pseudomorphs after olivine in a groundmass of about equal amounts of perthitic orthoclase and plagioclase—oligoclase and oligoclase-albite. (Query: porphyritic augite monzonite?)

The minor intrusions on both islands consist of dikes and sheets, and are lamprophyres, basalts, and a few felsites. The lamprophyres are all vogesites and generally strike in an east-and-west direction. The northwest dikes are olivine "dolerites" and monchiquites, the former being fine-grained dark rocks, rarely porphyritic or vesicular, of perfect ophitic texture, and consist of olivine, some biotite, zonal feldspars of labradorite with oligoclase rims in some places, and purple augite. The rock is a typical olivine diabase as the term is used in America. A variety of this rock but containing a considerable amount of analcite and zeolites occurs and of this the authors say it "may be described as analcite-bearing dolerite." To this rock the new name *Crinanite* is given. It is thus described:

The *crinanites*, then, are dark-coloured, fine-grained basic rocks consisting mainly of olivine, augite, and plagioclase felspar, with a considerable amount of analcite and zeolites. Olivine is abundant in small grains more or less altered to serpentine. The augite is always purple and is sometimes bluish

or plum-coloured; it is pleochroic . . . . and the extinction angle about 44°. The pyroxene in fact belongs to the variety usually described as titaniferous and much resembles that which occurs in many basic nepheline-rocks and teschenites. Chemical analysis proves that the crinanites are rich in titanium. . . . . The felspar has albite (rarely Carlsbad or pericline) twinning and belongs mostly to labradorite, though the outer zones are more rich in soda and may consist of oligoclase or albite. The iron oxides form irregular plates often fringed with small scales of dark brown biotite.

Most of these rocks have very perfect ophitic structure, and the augite occurs as small angular patches between the lath-shaped felspars or enclosing them. . . . . In a few specimens there are large corroded felspar phenocrysts consisting mainly of bytownite. Analcite and radiating clusters of zeolites fill up spaces bwteeen the felspars or occupy small rounded steam cavities. Perfectly transparent analcite is not uncommon, but often this mineral is turbid and granular with weak double refraction. The radiate zeolite appears to be mostly natrolite. Evidently these have been the last minerals to crystallise, and as the rocks are often very fresh, it is difficult to believe that they have originated from the decomposition of the felspar. They are more properly a pneumatolytic infilling of interstitial spaces during a period immediately following the crystallisation of the pyrogenetic minerals. Carbonates and chlorite are often associated with them, and veins of analcite and zeolites, easily distinguished by their low refractive indices, often ramify through the substance of the felspar.

In their composition and in the properties of their minerals these crinanites bear much resemblance to the teschenites . . . . but the teschenites are much coarser-grained, less frequently porphyritic and contain much more alkali felspar. The teschenites occur as large sills or laccolites, the crinanites as narrow vertical dykes which often can be followed for long distances in nearly straight lines. The crinanites in Colonsay show transitions to the camptonites, and are associated with monchiquites, some of which contain nepheline.

Monchiquite occurs in dikes and is composed of altered olivine, biotite, hornblende, and augite in a groundmass of analcite and carbonates. A nephelite ouachitite also occurs. The "felsite" dikes are described as "for the most part too decomposed for petrological examination."

The authors further describe the tectonics of the islands, their glaciation, and their economic resources.

In Part II the geology of the south part of the Ross of Mull is briefly described. The rocks here consist of metamorphosed sediments, intrusive granite and diorite, and dikes of vogesite, porphyrite, monchiquite, camptonite, "dolerite," and granophyre.

ALBERT JOHANNSEN

DAY, ARTHUR L., AND SOSMAN, ROBERT B. "The Melting-Points of Minerals in the Light of Recent Investigations on the Gas Thermometer, *Am. Journ. Sci.*, XXXI (1911), 341–49.

This article brings under one cover the previously published determinations of melting and other transition points made on the gas thermometer. One table contains the determinations that are considered accurate and another those that are only approximate. A bibliography of the original papers in which these results appeared is added.

ALBERT D. BROKAW

IDDINGS, JOSEPH P. *Rock Minerals, Their Chemical and Physical Characters and Their Determination in Thin Sections.* Second edition, revised and enlarged. New York: John Wiley & Sons, 1911. 8vo, pp. xiii+617; figs. 500; and 1 colored plate.

The issue of a second edition of Professor Idding's book so soon after the first is an indication of its success. In this revised work but little change has made been in the first part; the insertion of a page and a half on pleochroic halos and the substitution of Michel-Lévy's recent, for his old diagram of extinction angles on combined Carlsbad and albite twins, being all. The second part is increased by 66 pages by the addition of about eighty minerals, chiefly those occuring in pegmatites and as segregated ores, representing extremes of magmatic differentiation.

ALBERT JOHANNSEN

LEBEDEW, P. "Experimentelle Untersuchung einiger binärer Systeme von Silicaten," *Annales de l'Institute Polytechnique Pierre le Grand à St. Pétersbourg*, XV (1911), 690–720, figs. 2+11.

This article is in Russian with a two-page résumé in German. The studies are devoted to a diopside-olivine system and an anorthite-wollastonite system. In the first the eutectic point is reached with 40 mol. per cent olivine; in the second with 30 mol. per cent anorthite. Freezing-point curves of mixtures are plotted. In the résumé no question is raised as to whether either of these systems is a simple binary system. In the opinion of the reviewer the second at least should be considered a ternary system—either a part of the CaO–Al_2O_3–SiO_2 system studied by Shepherd and Rankin, or of a $CaSiO_3$–$CaAl_2Si_2O_6$–Al_2SiO_5 system, neither of which is so simple as the diagrams and the German résumé seem to indicate.

ALBERT D. BROKAW

LOEWINSON-LESSING, F. "Ueber die chemische Natur der Feldspath amphibolite, *Annales de l'Institute Polytechnique Pierre le Grand à St. Pétersbourg*, XV (1911), 559–76. 32 analyses.

The article is in Russian with a three-page résumé in German. The author shows that the feldspar amphibolites do not all fall into the chemical type of gabbro or diabase. In his 32 analyses he recognizes the following types: Melaphyre, Essexite, Gabbro-Norite, Vogesite Tephrite basalt, Shonkinite, Diabase, Gabbro-syenite Basanitic magma, Camptonite, two transition types, and certain special types not represented by any known eruptive rock.

According to texture the feldspar amphibolites are divided into four groups as follows: glomeroblastic, microgranitic, hornfels structure, and anomalous porphyritic texture.

Emphasis is placed on the lack of identity of chemical type in the feldspar amphibolite group.

ALBERT D. BROKAW

LOEWINSON-LESSING, F. "Ueber eine bisher unbeachtet kristallochemische Beziehung," *Centralblatt für Mineralogie, Geologie, und Paläontologie*, Jahrg. 1911, pp. 440–42.

The writer recalls the fact that double salts and hydrates usually crystallize with lower symmetry than the respective simple salts and anhydrous bodies and proceeds to point out that such minerals as may be considered compounds of a silicate and a non-silicate have higher symmetry than the constituent silicate. As examples he cites: Nephetite is hexagonal, while noselite, sodalite, and hauynite are isometric. Albite is triclinic while marialite (albite+NaCl) is tetragonal. Similarly helvite, danalite, melinophane, leucophane, the melanocerite group, and certain other complexes of this sort all develop higher symmetry than their silicate constituent alone. Apparently the symmetry of the non-silicate constituent is neglected.

ALBERT D. BROKAW

SCHNEIDER, KARL. *Die vulkanischen Erscheinungen der Erde*. Berlin: Gebrüder Borntraeger, 1911. Pp. viii+272, figs. and maps 50. M. 12, unbound.

The author has compiled, from many scattered and sometimes not readily accessible sources, data on vulcanism; much of the information being here brought together for the first time. The presentation is chiefly descriptive, genetic explanations rarely being given.

Vulcanism is defined as that phenomenon by which juvenile materials are brought from the interior of the earth into or upon its crust. These materials are divided into three groups: "rheumatitische" (ῥεῦμα, to flow), or that material which was poured out in a molten condition, "klasmatitische" (κλασμα, broken, fractured), material that is angular, broken, or rounded, and "pneumatolitische," or gaseous material. Since observations of eruptions cannot always be used in determining the history of a volcano, a morphological, topographical, geologic, petrographic, chemical, and physical study of previous eruptions must be made of former lava flows. The author gives his objections to the application of local for specific names for certain phenomena, as is done in the nomenclatures of Seebach and Stübel.

The most striking feature of a volcano is its built-up cone, and it is upon a study of the various characteristic forms which may be easily correlated with ideal sections, and upon a study of the materials which built up these cones, and of the forces which produced them, that the safest and most positive classification can be built. Too little regard, says the author, has heretofore been paid to "klasmatitische" material and he proposes a classification based upon the forms of the hill produced by the erupted material. Yet the author's own statement that the klasmatitic material may become the sport of the wind or be carried off by rainfalls shows how the outlines of a volcano may be altered to a remarkable degree in different latitudes. This would invalidate the classification to some extent, for it is, after all, based upon the topographic forms produced by the materials not carried away. Neither does the classification take into consideration the gaseous emanations upon which the character of an eruption somewhat depends.

Seven different types of volcanoes are recognized according to size, structure, and form.

"Pedionites" are characterized by the great extent of their lava flows. No volcano of this type is known for certainty in historic times. The material is generally rheumatitic though some klasmatitic is found. The Deccan is an example of a pedionite.

"Aspites" are characterized by bases which are wide in proportion to their height. They usually have a crater on the summit and the material is generally rheumatitic. Mauna Loa is an example. Vesuvius is a pseudoaspite.

"Tholoides" have slopes of over 35° and are convex upward. Like the preceding, the material erupted is rheumatitic but the height of the cone is greater in proportion to its base. This form is characteristic of

the older volcanoes, and Puy de Dome and Puy de Sarcouy are typical. In modern times it is rare, the cone Georgious on Santorin being the only one known to form in historic times.

"Belonites" have much greater height than base. They are easily destroyed, consequently few remain, Pelée being the only one recently formed.

"Konides" are related to Tholoides in having an intermediate base relative to height. The flanks are always concave upward and the material is chiefly klasmatitic, though much is rheumatitic. In many cases there is a crater on the peak. It is the type of most recent volcanoes and Fujiyama is a good example.

"Homates" are characterized by an increase in base and a decrease in height but on the whole they are small in their dimensions. They all surround a crater with the slopes inside and outside about equal and concave upward. The material is usually klasmatitic. Many recent volcanoes are of this type and many such cones occur on, or in, the craters of konides. Monte Nuovo, Hverfjell in Iceland, and some of the piperno volcanoes of the Campi phlegraei belong here.

"Maare." These have usually been called diatremes. In typical form they are of elliptical cross-section and penetrate the older formations without having built up cones at the surface. These volcanic tubes are not rare since Tertiary times and are of several types, depending upon the force of the eruption. When the tubes extend straight through the surrounding strata the author classifies them as of the "Alb" type when the older strata are bent downward, at the sides, they form the "Fife" type, when they are bent upward at the sides, the "Cape" type. In the "Rez" type the strata are bent upward around the tube but the material does not reach entirely to the surface. These are Lachmann's hemidiatremes.

In tabular arrangement these forms may be grouped as follows:

Older	Rheumatitic forms	Older forms	Pedionite
			Aspite
		Younger forms	Tholoide
			Belonite
Intermediate	Rheuklastitic forms	.....	Konide (Pseudoaspite)
Younger	Klasmatitic forms	.....	Homate
			Maare

The cycle of activity appears somewhat as follows. In the full strength of a volcano's activity the material ejected is rheumatitic and a pedionite is formed. The activity gradually becomes less, and aspites, finally tholoides and belonites appear. Sometimes succeeding the aspite stage there is an alternation of rheumatitic and klasmatitic material, and konides are formed, the klasmatitic material forming homate cones during the process. Sometimes the intermediate konide stage does not appear and aspites are followed directly by homates or contain them in the later stages. When the activity decreases still further the pneumatolitic stage is reached and the cycle is closed.

The formation of pedionites, aspites, or konides extends through a long period of time, while homates and maares have a brief period of development. The explosive process can represent only a single act after whose conclusion the activity must be closed forever. Nowhere do other forms succeed tholoides or belonites, but pedionites and aspites are succeeded by younger forms. Konides always show, in their entire cone, the story of the altering forces. They often carry on their extinguished summits the youthful, rapidly built homates, the work of a short explosive outbreak. Since the sequence is never reversed, the subsequent history of a volcano can be predicted, and the close of a cycle is indicated by the form of its last outburst. A volcano cannot be considered as active simply because, like Monte Nuovo and El Nuovo, it has had an eruption within historic times. From the forms of these cones it is seen that they will never again be active. Other volcanoes, such as Tambora, Tarawera, and Krafla, which began their activity in Tertiary times, are to be considered extinct also, for their last eruptions were of klasmatitic material only. This fact is of significance when it is applied to such volcanoes as Adatura or Dekeyama in Japan which, while it has had no outbreak in 2,100 years, has during all that time given off considerable pneumatolitic exhalations. The last outbreaks, however, were klasmatitic, and the types are those of the closing cycle.

The forms, then, of the cones produced, give the key for the determination of the stage of a volcano's history. To say that a volcano, which has erupted within the knowledge of man, may again become active, or that one which has never within historic times broken forth is extinct, is to base the assertion upon insecure data.

Succeeding the discussion of the classification of volcanoes, the author gives a chapter on the volcanic formations of central Europe since the Tertiary, and considers the geographic distribution of the active volcanoes of the present time. The chief volcanoes and volcanic zones are described

and sketch maps of their locations are given in very complete form, running through fifty pages of the book. The volume is concluded with a catalogue of volcanoes which have been active within historic times. Three hundred and sixty-seven are recorded with their names, latitude and longitude, absolute and relative height, and dates of eruption. As the author says in his introduction, the observations upon which the determination of activity is based are of very unequal value. For example, it may be noted that in the United States Mt. Hood is recorded as having been active in 1854, 1859, 1865, and 1866; Mt. Baker in 1843, 1853, and 1859; Mt. Ranier in 1841, 1843, and 1894; and Mt. St. Helens in 1837(?), 1841, 1842, 1854, and 1889. The author does not give his authority for the dates of eruptions and there may be many other volcanoes listed whose activity is as doubtful as the American. Eruptions of Mt. Ranier and Mt. St. Helens within historic times are extremely doubtful. Mt. Baker may have been active in 1843, and smoke by day and a glow one night were reported to have been seen on Mt. Hood in 1907 from a distance of a number of miles. In no case, however, is there record enough to more than place the volcanoes of the United States in the doubtful list. While many references to the literature of different outbursts are to be found in the earlier chapters, it is to be regretted that a complete bibliography of the various eruptions is not given so that one might determine the relative value of the observations.

The presswork of the book is clean and good but its appearance is greatly marred by muddy half-tones and crude line drawings. Throughout the work the bibliographic references in general, are good and complete, and are given in footnotes.

ALBERT JOHANNSEN

SMOLENSKY, S. "Schmelzversuche mit Bisilicaten und Titanalen," *Annales de l'Institut Polytechnique Pierre le Grand à St. Pétersbourg*, XV (1911), 245–63; figs. 5+10.

These studies are devoted to melts of a $CaSiO_3$-$CaTiO_3$ system and a $MnSiO_3$-$MnTiO_3$ system. The first falls into Type III according to Roozeboom, having a minimum melting-point with 33.4 mol. per cent of $CaTiO_3$. The second falls into Type V, giving a discontinuous series of mix crystals having a eutectic point with 38.3 mol. per cent $MnTiO_3$. Curves of the two systems are plotted from experimental results. Attempts to study a similar system with barium salts were complicated by lack of knowledge of the polymorphism of $BaSiO_3$. The article is in Russian with a two-page résumé in German.

ALBERT D. BROKAW

WOLOSKOW, A. "Schmelzversuche über Bisilicate mit Sulfiden und Halogenverbindungen," *Annales de l'Institute Polytechnique Pierre le Grand à St. Pétersbourg*, XV (1911), 421–42, figs. 6; 4 photomicrographs.

The article is in Russian with a two-page résumé in German. Solidification curves were studied by means of a Kurnakow self-registering pyrometer. The results are as follows: $MnSiO_3$+MnS, eutectic with 6·85 mol. per cent MnS, 1130° C. $BaSiO_3$+FeS gave rise to a liquation of FeS and $BaSiO_3$ containing 10 mol. per cent FeS. $BaSiO_3$+BaS, eutectic with 25 mol. per cent BaS, 1325° C. $BaSiO_3$+$BaCl_2$, eutectic with 8 mol. per cent $BaSiO_3$, 902° C. Solidification curves of various mixtures are given.

ALBERT D. BROKAW

WÜLFING, E. A. *Ueber die Lichtbrechung des Kanadabalsams.* Sitz. Heidelberger Akad. Wiss., Math.-naturw. Kl., 1911, 20 Abhandl., pp. 1–26.

Calkins (*Science*, XXX [1909], 973), compared the indices of refraction of Canada balsam with various minerals in 300 thin sections from one to eight years old, and found that in only one case out of a hundred did the index of balsam exceed 1.544. The lowest value obtained was between 1.535 ± 0.002. He gives 1.54 as a fair mean, and says it rarely has an index of less than 1.535 or greater than 1.545. Schaller (*Am. Jour. Sci.*, XXIX [1910], 324), with an Abbé-Zeiss reflectometer, found that uncooked balsam in sodium light had an index of 1.524, soft-cooked an average of 1.5387, as usually cooked an average of 1.5377, and over-cooked an average of 1.5412 with a maximum value of 1.543. Wülfing in the fourth edition of Rosenbusch-Wülfing's *Physiographie*, Vol. I, Part I, p. 150, gave the value of the index of balsam as ± 1.54, and in the same volume, Part II, p. 345, said it varied between 1.542 nearly to 1.550.

In the present paper Wülfing gives determinations made by comparison with minerals in thin sections prepared 30 to 40 years ago, and also determinations made with an Abbé-Pulfrich total reflectometer which had been tested, for weeks previously, for errors. On a collection of thin sections prepared by Voigt and Hochgesang 30 years ago the value $n = 1.538 \pm 0.002$ in the central portions of the slides and at the borders, which had become yellow with age, $n = 1.5416$. On other sections values

between 1.5330 and 1.5382 were obtained, the mean value being $n=1.537\pm0.004$ In order to determine if there was any difference in the indices of the original balsam used, tests were made upon samples submitted by six different firms. Incidentally, in making these determinations, the values of the indices of refraction of certain minerals were obtained. It was found that chalcedony, when occurring in rather coarse fibers, is practically uniaxial and has indices $\alpha=\beta$ or $\omega=1.530$, γ or $\epsilon=1.538$. Hydrargillite has values for α and β considerably higher than usually given, at least equal to 1.57. In most cordierite, $\alpha=1.534\pm0.003$, $\beta=1.539\pm0.003$, $\gamma=1.541\pm0.003$. Nephelite, so far as the indices are concerned, is of two kinds; nephelite from Vesuvius (nephelite I) has $\omega=1.5418$ and $\epsilon=1.5378$, while elaeolite from Hot Springs, Ark., has $\omega=1.5466$ and $\epsilon=1.5417$.

In regard to Canada balsam, the author concludes that the indices of the majority of the slides of the Heidelberg collection lie between 1.533 and 1.541, and in only rare cases do they reach 1.544 or fall below 1.533, both cases being due to fault of manufacture. Balsam which has turned yellow does not always have a high index, but all balsam when exposed to the air discolors, becomes brittle, and increases in index. The balsam protected by the cover-glass or by a crust of balsam may retain its sticky consistency and low index even after 40 years; it is therefore, altered only on the surface or at the border of the cover-glass. Commercial balsams are so uniform that in the preparation of thin sections the limiting values of the index need not fall beyond 1.533 and 1.541, and, with practice, should be between 1.534 and 1.540.

ALBERT JOHANNSEN

Reviews

Grundzüge der Paläontologie. Von KARL A. VON ZITTEL. II. Abteilung. Vertebrata. Neubearbeitet von F. BROILI, E. KOKEN, M. SCHLOSSER. München und Berlin, 1911. Pp. 598.

Zittel's *Handbuch der Paläontologie*, the publication of which was completed nearly twenty years ago, marked the beginning of a new epoch in paleontology. And his compendium, or *Grundzüge*, the first edition of which was published in 1895, the English edition by Eastman in 1900–1902, has been of the greatest service to all students of the science. But the years that have elapsed since these editions appeared (and the English edition did not include the mammals) have greatly impaired their usefulness. The science of paleontology, and especially vertebrate paleontology, is progressing with such rapidity that even a few years leaves any text behind.

It is very doubtful whether other editors could have been found as competent for the present edition as Broili, Koken, and Schlosser. Additions and changes have been made with great conservatism, some will think with undue conservatism; but, in the opinion of the reviewer, conservatism here is a commendable fault, if fault it be. It will be time enough to accept the many new orders and suborders of vertebrates, the many changes in classification, which have been proposed in recent years when they shall have stood a longer test. In the past history of science the majority of such innovations are ultimately rejected.

Of the fishes, treated by Koken, six subclasses are accepted: the Placodermi, or Agnatha, Elasmobranchii, Holocephali, Dipnoi, Arthrodira, and Teleostomi. As regards the Arthodira the relations of which have been the subject of no little discussion in recent years, Koken rejects the evidence of Placodermi affinities and accepts those of the Dipnoi. "Die *Dipnoer* . . . . sind den *Arthodira* näher verwandt . . . . mit den *Placodermen* nicht so nah wie früher angenommen."

The revision of the Amphibia and Reptilia has been well done by Broili; one misses little that should be included in the work. The many new discoveries among extinct amphibia have been intercalated without change in the classification, notwithstanding the new schemes, especially those of Jaekel, which have been proposed—and which yet

await justification. Doubtless changes will be required at no very distant time, for the Lepospondyli, at least, as stated, are in a very unsatisfactory condition; but the present urgent need here as elsewhere among the ancient vertebrates is more facts, not more new theories.

Among the Reptilia, also treated by Broili, only one new order is admitted, the Parasuchia, concerning which there is now a unanimity of opinion; nor have additional suborders been admitted, perhaps unwisely, save the Chelonidea among the turtles. The union of the cotylosaur reptiles in the same order with the theriodonts seems ultra-conservative, and yet the reviewer must admit that there seems to be no broad line of demarcation in the series between the two extremes. The writer does not agree with Broili in his disposition of *Lysorophus* among the lizards, nor of *Placodus* and *Mesosaurus* among the Sauropterygia.

The treatment of the birds, by Schlosser, is essentially that of the Eastman edition, with minor changes.

Especially welcome is the part devoted to the mammals, including nearly half of the work. Dr. Schlosser's reputation as a mammalologist is deservedly high, and his views will have much authoritative value. The recent works by Osborn and Gregory are of the greatest value, but nothing can take the place of such a compendium as the present one, with its precise definitions and systematic arrangement. One is interested to observe that, in place of the twenty-eight orders of Osborn, Schlosser follows the usual classification of the placental mammals into the Insectivora, Rodentia, Chiroptera, Carnivora, Cetacea, Edentata, Ungulata, and Primates, while the Sirenia, Proboscidea, and Hyracoidea are grouped with the Embrithopoda under the order Subungulata, of African origin; and the chief groups of South American origin, the Typotheria, Toxodontia, Entelonchyia, Astrapotheroidea, and Pyrotheria are included under the order Notungulata. He classes the Monotremata and Marsupialia under the Eplacentalia. The Multituberculata, including even the disputed *Tritylodon*, are classed as marsupials, against which Dr. Broom and the present writer have protested. One can scarcely conceive of the possibility of the immediate evolution of reptiles into marsupial mammals in face of the oviparous mammals existing today. Notwithstanding the evidences afforded by *Ptilodus* the writer, as a herpetologist, firmly believes that the early multituberculate mammals were oviparous, with all the essentially primitive characters possessed by the living monotremes in the pectoral girdle, genital apparatus, etc.

Many new figures have been added to the work, but some have been retained which should have been rejected. Some minor errors are noticeable. Dr. Dall will be surprised to see that he is cited on page 177 as a writer on extinct frogs! The edition as a whole is very welcome to every student of extinct vertebrates; we only regret that the English edition might not also be brought up to date and the mammals included.

S. W. W.

"Beiträge zur Kenntnis der Oligozänen Landsäugetiere aus dem Fayum (Aegypten)." By MAX SCHLOSSER. *Beiträge zur Paläontologie und Geologie*, XXIV (1911), pp. 51–167; Pls. IX–XVI.

Perhaps no discoveries of extinct animals in recent years have excited more general interest than those of the Oligocene of the Fayum in Africa, as first made known by Beadnell and Andrews and later by Osborn. The present contribution by Schlosser, based upon extensive collections made for the Stuttgart Museum, adds very materially to this interest. In it he describes and figures new creodonts and rodents, an insectivore, a bat, and three new genera of primates of especial interest. And our knowledge of the Hyracoidea is also materially increased by the addition of much new material—"so dass die Andrewsche Monographie auch für diese Gruppe volkommen veraltet erscheint."

Most interesting of his discoveries is the new simiid *Propliopithecus;* and but little less so are his new genera *Parapithecus* and *Moeropithecus*, the former representing a new family of anthropoids. *Propliopithecus* he believes has a direct genetic relationship with *Homo:* "Aber auch für die Ableitung der Gattung *Homo* und wohl auch der Gattung *Pithecanthropus* (wenn nicht mit *Homo* identisch) von den oligozänen Genus *Propliopithecus* besteht kein prinzipielles Hinderness, denn in den oben berücksichtigen Merkmalen hat die Gattung *Homo* mit *Propliopithecus* sogar entschiedene grössere Aehnlichkeit als alle lebenden Simiiden-Gattungen." And he thinks that the recognition of this African antecedent of *Homo* is to be welcomed as doing away with the necessity of resorting to eoliths as proof of the existence of ancient Man. "If now *Propliopithecus* is the direct ancestor of Man the impossibility of his making eoliths is evident, since *Propliopithecus* had probably only the body dimensions of a human infant, and that so small a creature could have used stones of the size of the usual eoliths no one will seriously affirm." In the evolution of the Hominidae, aside from the gradual increase in body size, there has been a shortening of the premolars, a

decrease in size of the canines, and a development of an arched form of the lower jaws. He complains that many paleontologists have not appreciated the law of increase in size as a fundamental one in evolution, but, if the mammalologists have not appreciated it, surely other paleontologists have.

As regards the relationships between the South American and the Old World and North American mammalian faunas he says: "While the other orders are already represented in the South American *Notostylops* fauna, we have to deal, especially in the rodents and primates, with new faunal elements which must have gone thither either in the Oligocene or at the beginning of the Miocene. And they could have gone only from Europe or northern Africa, since, as we have seen, these rodents are closely related to the European forms, and the primates have at least a closer relationship with those of the Fayum than with those of the North American Eocene. There must, therefore, have been a connection between South America and the Old World in the Oligocene or at the beginning of the Miocene." This theory has already been urged by Ameghino. "This connection could not have been a broad land bridge, otherwise there would have been an exchange of the larger mammals, which did not occur till the Pliocene." He suggests that this migration of the smaller animals may have occurred from island to island of an archipelago, the creatures possibly carried by the larger birds of prey. And he thinks also that about the same time there was a like exchange of the smaller mammals between North America and Africa.

S. W. W.

The Cid Mining District of Davidson County, North Carolina. By JOSEPH E. POGUE. Raleigh: *Bull. No. 22 North Carolina Geol. Survey*, 1910. Pp. 144; Plates 22.

This district is located in the central portion of the Piedmont Plateau and includes areas of slate, tuffs, volcanic breccia, rhyolite, dacite, and andesite, cut by gabbro and diabase dikes. All but the dike rocks range from a massive to a schistose condition with sericite and greenstone schists as the final product of dynamic metamorphism. The slates are interbedded with rhyolitic and dacitic tuffs. The coarser acid volcanic breccia grades into rhyolite flows and is thought to be a flow breccia. The gabbro dikes are approximately parallel to the schistosity and are cut by diabase dikes, said to be Triassic. The evidence as to the Triassic

age of the latter is inconclusive as it rests on the fact that they cut Triassic sandstones. On this evidence they might be post-Triassic.

The region comprises a series of folds, beveled to the present surface, and one great overthrust fault. The jointing, folding, faulting, and schistosity are referred to the same epoch of compression.

Four types of ore bodies are noted, namely impregnations in the schists, stringer leads in quartz, parallel to the schistosity, quartz veins cutting the schistosity, and replacement deposits.

The ore minerals are auriferous pyrite, chalcopyrite, galena, and zinc blend. The deposits are referred to magmatic waters, perhaps emanating from a granitic mass a few miles west. The time of deposition is placed after metamorphism. In view of Emmons' recent work in Maine and Tennessee the evidence on this last point needs to be more carefully worked out.

A. D. B.

The Iron Ore Supply of Japan. By KINOSUKE INOUYE. "The Iron Ore Resources of the World." Stockholm, 1910. Pp. 927–69; Plates 4; Figs. 13.

The iron ore deposits of Japan are classified in six groups as follows:

I. Magmatic segregations in granite. Not of economic importance under present conditions.

II. Bedded deposits usually in connection with radiolarian quartzites and slates of Paleozoic and Mesozoic age. The ores carry from 20 to 50 per cent iron with silica up to 40 per cent. They are usually rather high in phosphorus.

III. Contact deposits in limestone near contact with intrusives. These are the most important ores of Japan. The ore is chiefly magnetite with minor amounts of micaceous hematite and limonite. The iron content averages from 55 to 60 per cent with some analyses giving over 69 per cent. The ores are mixed with contact minerals and quartz and in some cases contain pyrite and chalcopyrite.

IV. Veins in various kinds of rocks. Not of great importance under present conditions.

V. Limonite deposits derived from the decomposition and redeposition of pyrite or magnetite deposits or by deposition from ferruginous springs. These are next in importance to class III.

VI. Alluvial deposits of iron sand derived from the decomposition of older rocks.

The amount of ore in sight is estimated at 19,000,000 metric tons;

probable ore, 37,000,000 metric tons, in addition to this amount. Low-grade ore, high in silica but of possible economic importance, 4,000,000 metric tons. A table of about 175 analyses of ores from various locations is added.

A. D. B.

The Iron Ore of Corea. By KINOSUKE INOUYE. "Iron Ore Resources of the World." Stockholm, 1910. Pp. 973–81; Plate 1.

Three types of deposits have been recognized, namely magmatic segregations, bedded deposits, and contact deposits, but little is known regarding the occurrence of the ores. The present output is about 70,000 metric tons per year, mostly limonite, with some hematite and magnetite. In one district a rough calculation gives 4,000,000 metric tons above level ground, but for the rest of Corea data are lacking. The producing mines are briefly described and a number of analyses are inserted. The iron content varies from 29 per cent in one of the contact ores to 70 per cent in one of the magnetite ores.

A. D. B.

Building Stones. By JOHN WATSON. Cambridge, 1911. Pp. 483.

This is a descriptive catalogue of the specimens of British and foreign building stones in the Sedgwick Museum, Cambridge, England. The rocks are grouped according to origin as igneous plutonic, igneous volcanic, metamorphic, and sedimentary. The sedimentary rocks are subdivided according to their geologic age. Under each of these divisions the rocks are taken up by countries and about half of the book is devoted to their occurrence, texture, and uses. The remainder of the book is the catalogue proper, giving the name and location of specimens by number. Brief notes as to color and texture, and in most cases chemical analyses and crushing tests are added.

A. D. B.